

## CHAPTER III SUMMARY OF TROPICAL CYCLONES

### 1. WESTERN NORTH PACIFIC TROPICAL CYCLONES

During 1979, the western North Pacific experienced a below normal year of tropical cyclone activity with a total of 28 cyclones (Table 3-1). By comparison, 1978 was a near normal year with 32 cyclones and 1977 was a near record low year with a total of 21 cyclones. Five significant tropical cyclones never developed beyond tropical depression (TD) stage, and nine developed into tropical storms (TS). Of the 14 cyclones that devel-

oped to typhoon (TY) stage, only 4 reached the 130 kt (67 m/sec) intensity necessary to be classified as a super typhoon (ST). This season, beginning with Typhoon Bess, tropical cyclones attaining tropical storm strength or greater were assigned names on an alternating male/female basis. This change was a result of the 1979 Tropical Cyclone Conference, and the list of names can be found in CINCPACINST 3140.1N CH-1. A similar but different series of cyclone names is used for eastern North Pacific and North Atlantic cyclones. Each tropical cyclone's

TABLE 3-1.

WESTERN NORTH PACIFIC

#### 1979 SIGNIFICANT TROPICAL CYCLONES

<u>CYCLONE</u>	<u>TYPE</u>	<u>NAME</u>	<u>PERIOD OF WARNING</u>	<u>CALENDAR DAYS OF WARNING</u>	<u>MAX SFC WIND</u>	<u>MIN OBS SLP</u>	<u>NUMBER OF WARNINGS</u>	<u>DISTANCE TRAVELLED</u>
01	TY	ALICE	01 JAN-14 JAN	14	110	930	51	2597
02	TY	BESS	20 MAR-25 MAR	6	90	958	21	1804
03	TY	CECIL	11 APR-20 APR	10	80	965	40	2535
04	TS	DOT	10 MAY-16 MAY	7	40	984	24	2876
05	TD	TD-05	23 MAY-24 MAY	2	30	998	6	2170
06	TY	ELLIS	01 JUL-06 JUL	6	85	955	22	1612
07	TS	FAYE	01 JUL-06 JUL	6	40	998	20	1837
08	TD	TD-08	24 JUL-25 JUL	2	20	1004	5	1264
09	ST	HOPE	27 JUL-03 AUG	10	130	898	33	3928
10	TS	GORDON	26 JUL-29 JUL	4	60	980	13	1058
11	TD	TD-11	03 AUG-06 AUG	4	25	997	14	1088
12	TY	IRVING	09 AUG-18 AUG	10	90	954	38	2732
13	ST	JUDY	16 AUG-26 AUG	11	135	887	39	2502
14	TD	TD-14	18 AUG-20 AUG	3	20	1006	9	605
15	TS	KEN	01 SEP-04 SEP	5	60	985	13	1418
16	TY	LOLA	02 SEP-08 SEP	7	90	950	23	1298
17	TY	MAC	15 SEP-24 SEP	10	70	984	35	1831
18	TS	NANCY	19 SEP-22 SEP	4	45	993	14	528
19	TY	OWEN	22 SEP-01 OCT	10	110	918	37	2151
20	TS	PAMELA	25 SEP-26 SEP	3	45	1002	6	984
21	TS	ROGER	03 OCT-07 OCT	6	45	985	16	1920
22	TY	SARAH	04 OCT-15 OCT	12	110	929	43	1194
23	ST	TIP	05 OCT-19 OCT	16	165	870	60	3972
24	ST	VERA	02 NOV-07 NOV	6	140	915	23	1868
25	TS	WAYNE	08 NOV-13 NOV	6	50	990	22	1559
26	TD	TD-26	01 DEC-02 DEC	2	30	998	6	1070
27	TY	ABBY	01 DEC-14 DEC	14	110	951	52	4044
28	TS	BEN	21 DEC-23 DEC	3	60	990	10	2245

1979 TOTALS

149\*

695

\*OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM.

maximum surface wind (MAX SFC WND), in knots, and minimum observed sea-level pressure (MIN OBS SLP), in millibars, were obtained from best estimates of all available data. The distance travelled, in nautical miles, was calculated from the JTWC official best track (see Annex A).

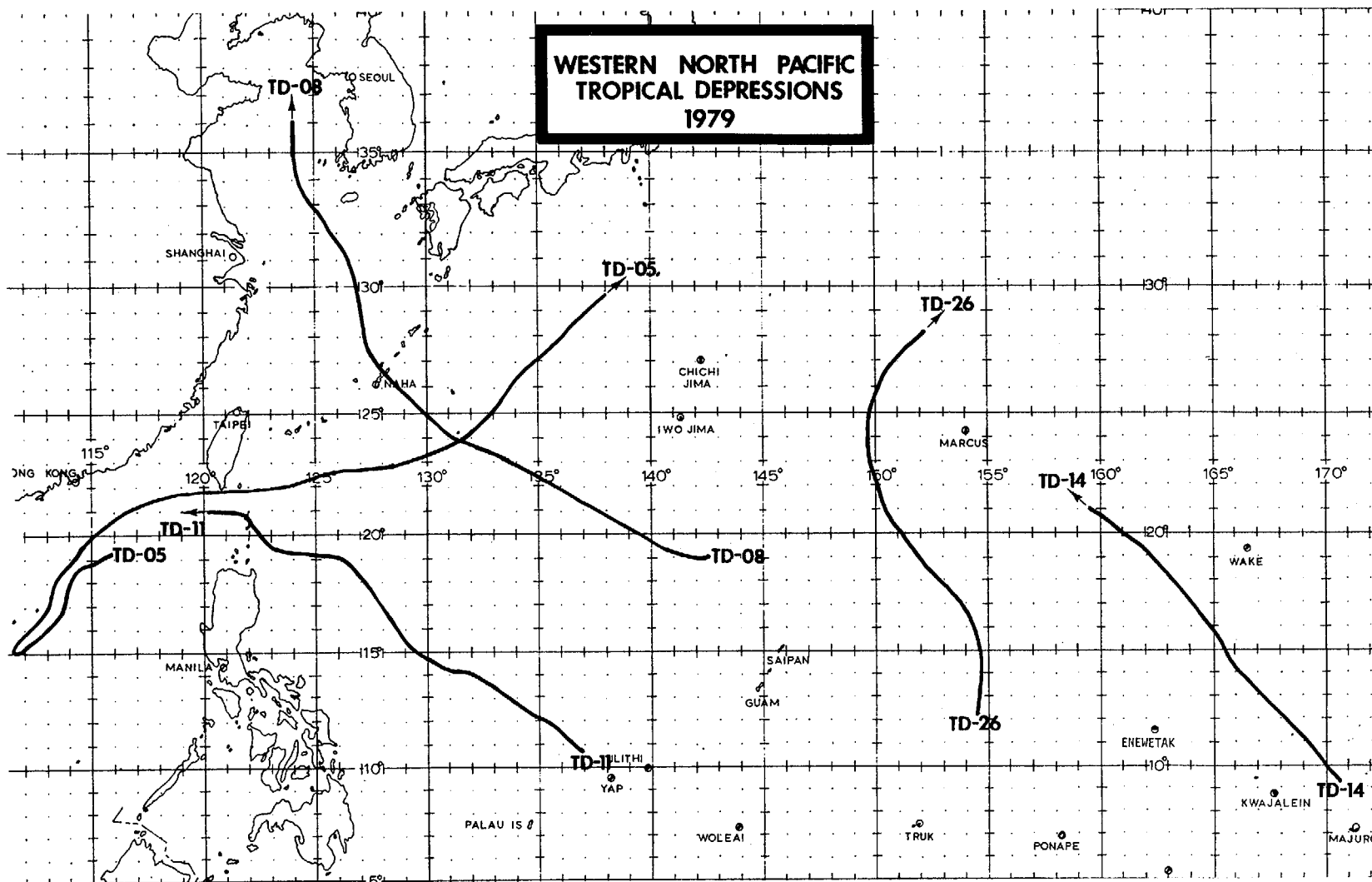
Table 3-2 provides further information on the monthly distribution of tropical cyclones and statistics on Tropical Cyclone Formation Alerts and Warnings. Even though there were 4 fewer cyclones this season compared to last season, there were 18 more warning days.

TABLE 3-2.

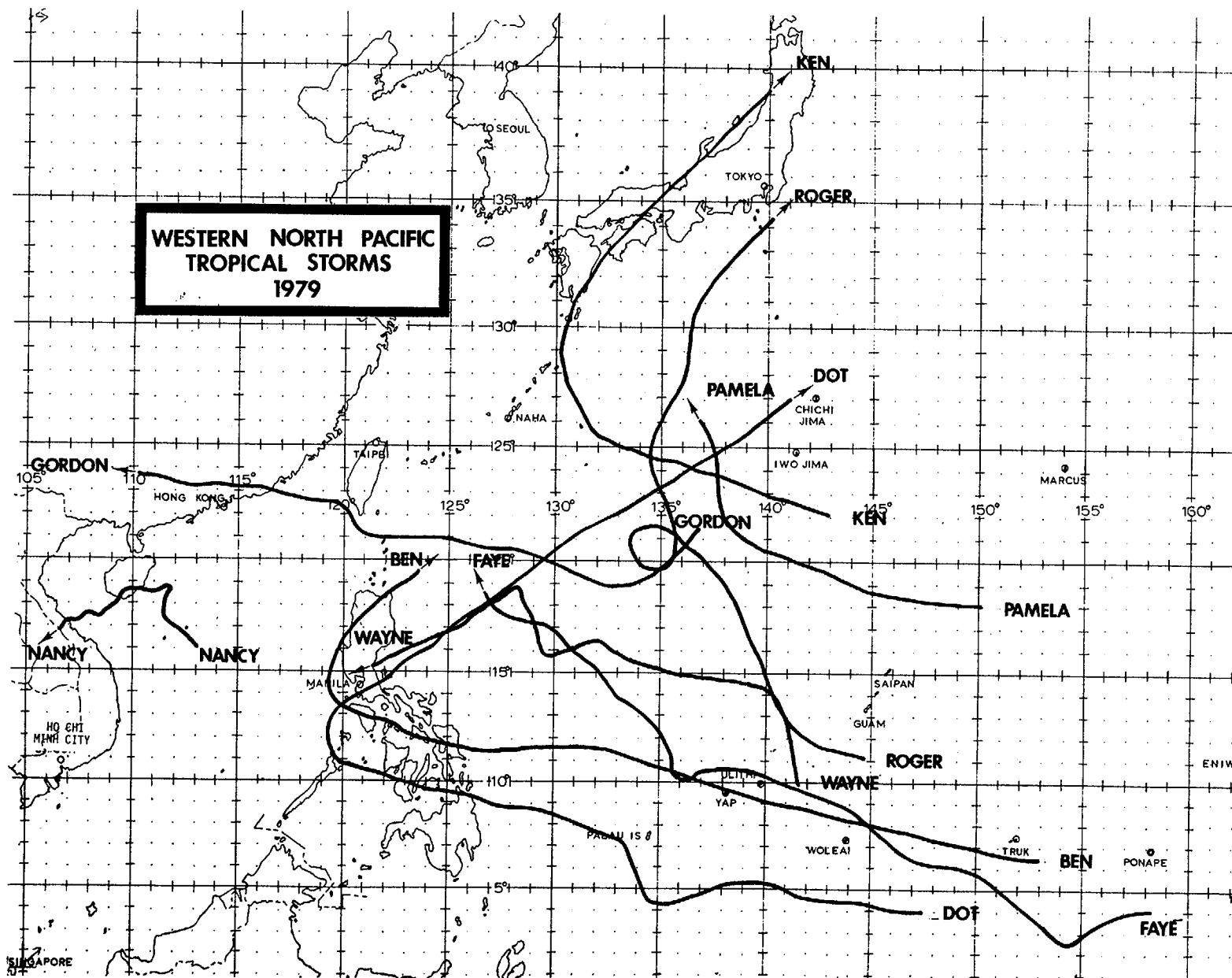
1979 SIGNIFICANT TROPICAL CYCLONE STATISTICS

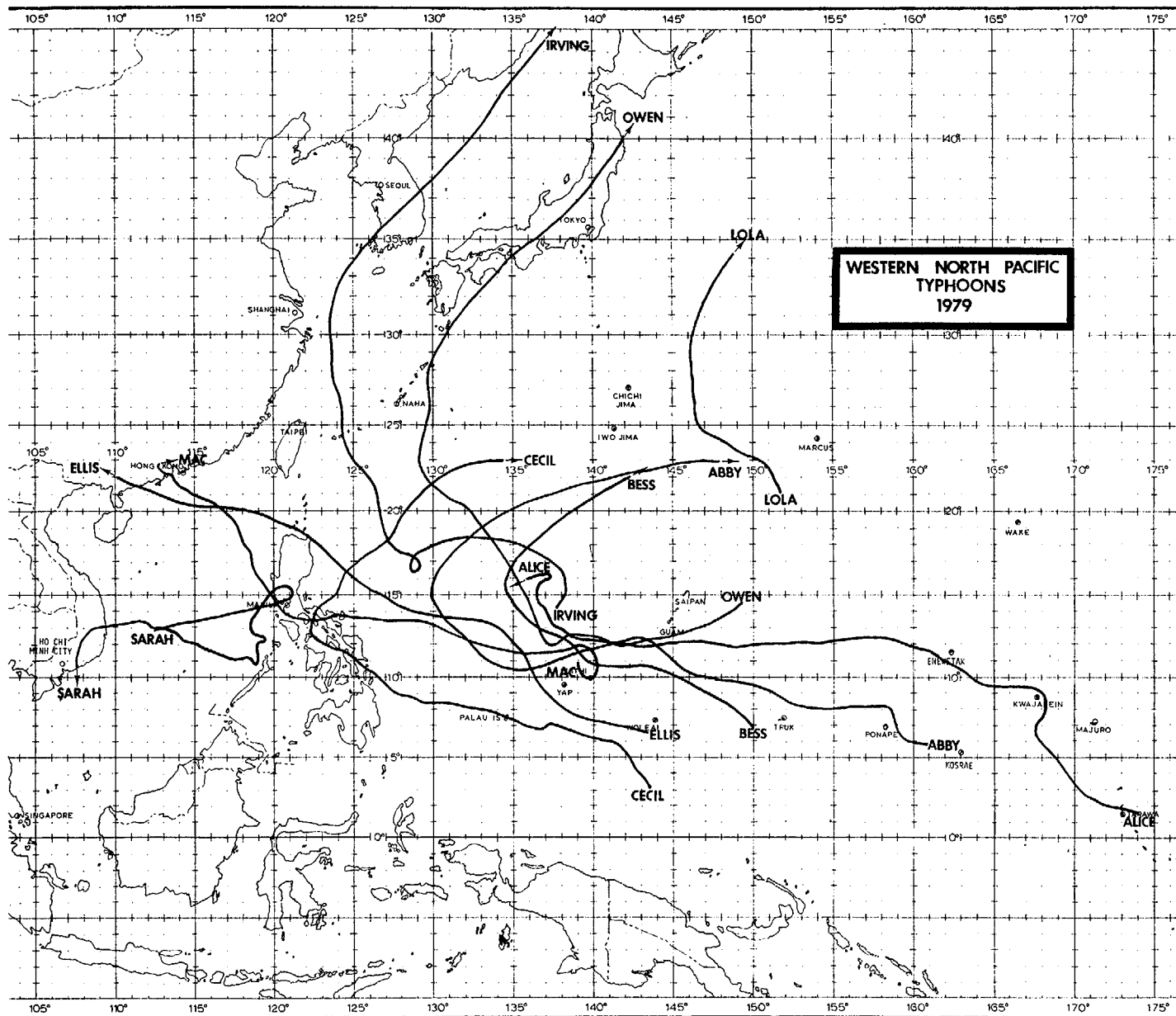
WESTERN NORTH PACIFIC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	(1959-78) AVERAGE
TROPICAL DEPRESSIONS	0	0	0	0	1	0	1	2	0	0	0	1	5	4.8
TROPICAL STORMS	0	0	0	0	1	0	2	0	4	1	1	1	10	10.0
TYPHOONS	1	0	1	1	0	0	2	2	2	2	1	1	13	18.0
ALL CYCLONES	1	0	1	1	2	0	5	4	6	3	2	3	28	32.8
(1959-78) AVERAGE	0.6	0.4	0.6	0.9	1.4	2.1	5.2	6.8	6.0	4.8	2.7	1.3	32.8	
FORMATION ALERTS	23 of the 27 (85%) Formation Alert Events developed into tropical cyclones. 5 of the 28 (18%) tropical cyclones did not have a Formation Alert.													
WARNINGS	Number of warning days: 149 Number of warning days with 2 cyclones: 38 Number of warning days with 3 or more cyclones: 5													

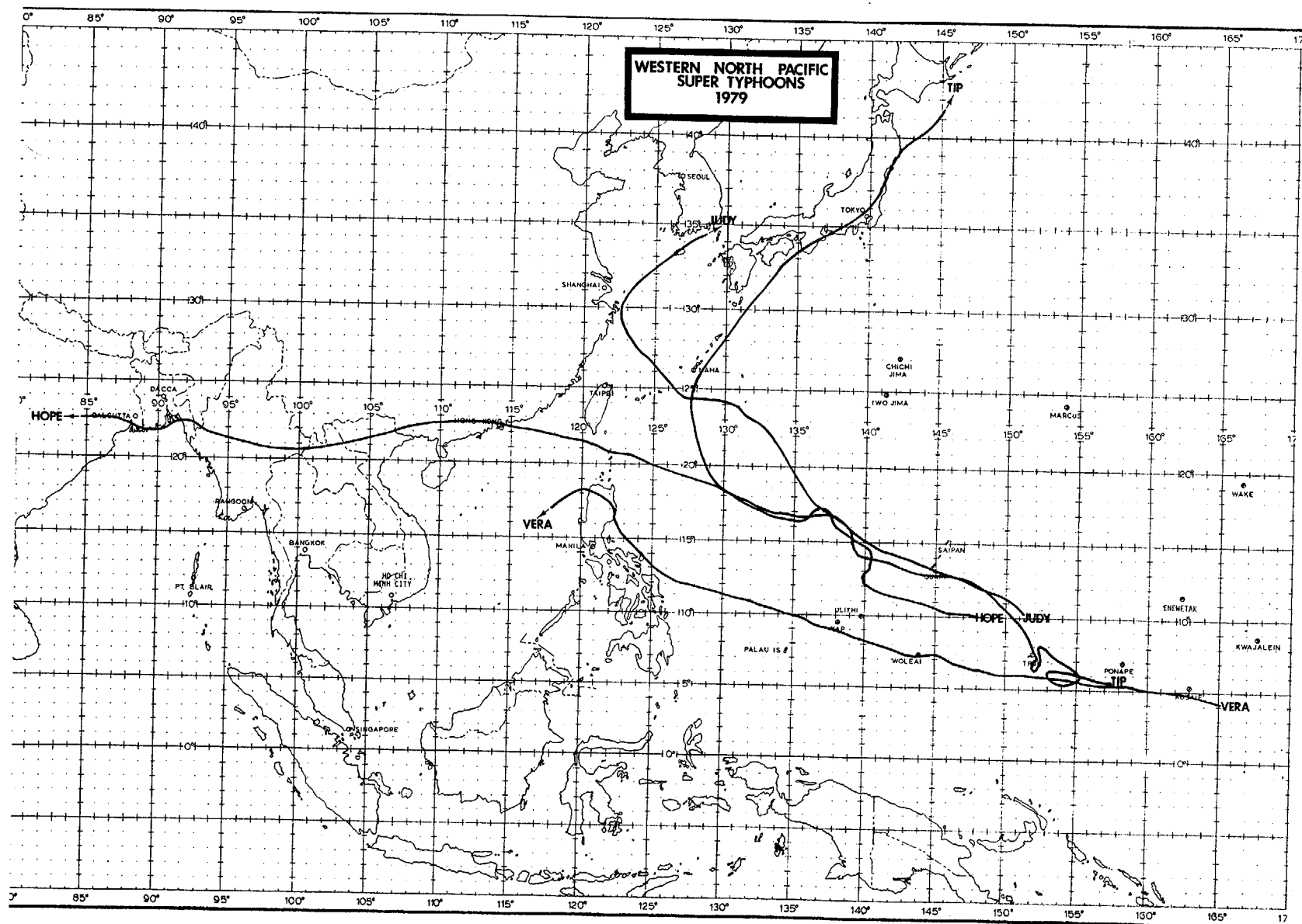
# WESTERN NORTH PACIFIC TROPICAL DEPRESSIONS 1979

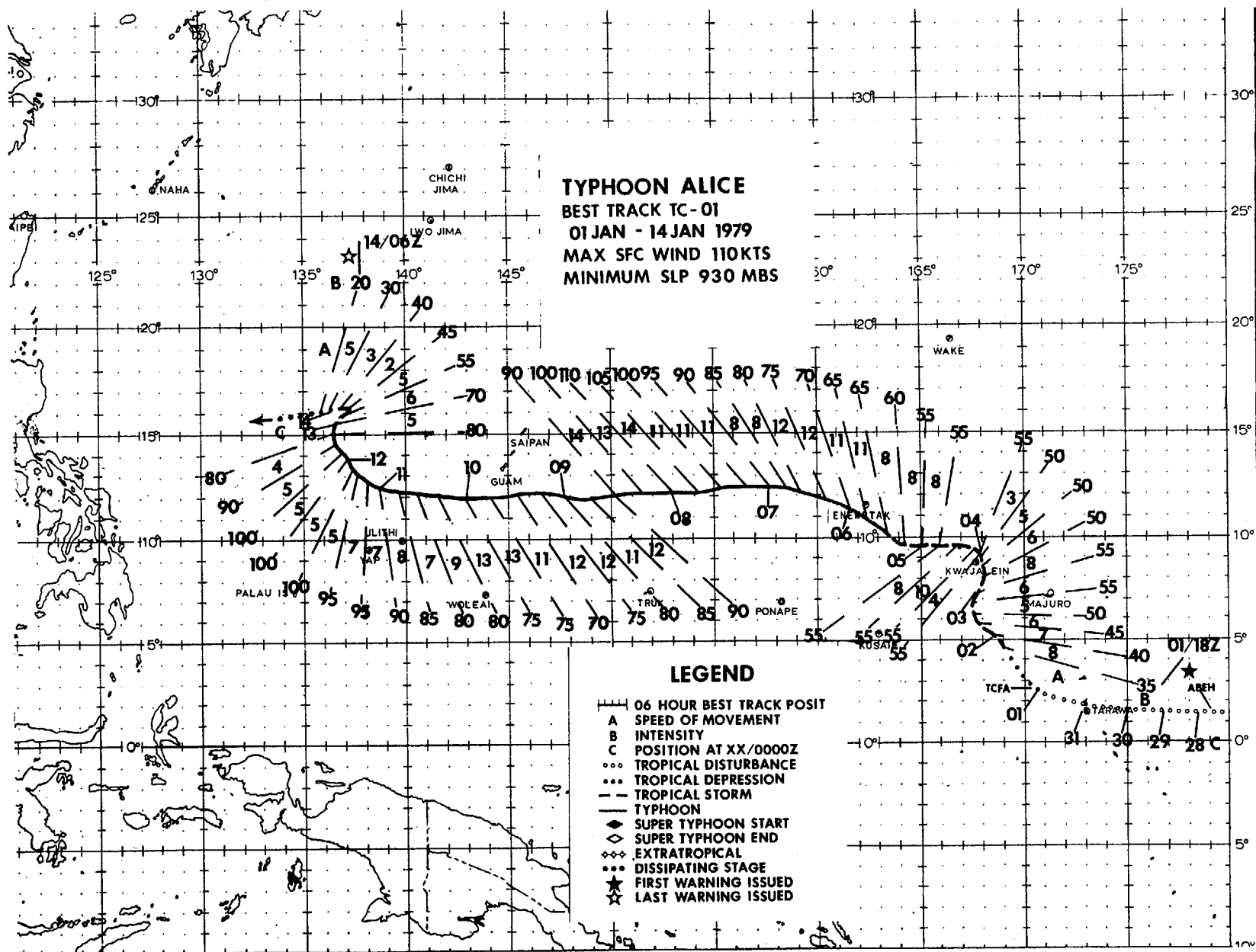


**WESTERN NORTH PACIFIC  
TROPICAL STORMS  
1979**









# TYPHOON ALICE (01)

Typhoon Alice, the first tropical cyclone of the 1979 season, was actually first sighted as a tropical disturbance on the 27th of December 1978. Being over the Gilbert Islands quite close to the equator, the potential for development was considered poor. A tropical cyclone formation alert was issued at 0300Z 1 January 1979 when satellite data showed the disturbance progressively increasing in organization. Soon after, the suspect area accelerated northwest to higher latitudes where development conditions were more favorable, and by 011800Z, tropical storm Alice was named. Post-analysis showed that the tropical depression stage began near 010000Z at low latitudes, contrary to the general rule that cyclones do not form close to the equator.

Although a climatologically unfavorable period for western North Pacific tropical cyclone development, the fact that Alice did form supports the non-existence of a definitive "typhoon season" for WESTPAC; tropical cyclones are possible anytime of the year. The greatest forecasting difficulties and concomitant large forecast errors occurred during Alice's formative and dissipating stages. Double intensification also contributed to Alice's notoriety.

Early in her lifetime, Alice meandered through the Marshall Islands as if determined to visit each island. One week later, on 12 January 1979, President Carter declared the Marshall Islands a major disaster area.

A satellite reconnaissance fix at 022133Z showed Alice had moved northeastward when forecast to continue northwestward. Being a fix on a poorly defined satellite image (PCN 6), it was not taken verbatim; northwest movement continued to be forecast. An aircraft reconnaissance fix at 030053Z confirmed the earlier satellite fix as did a follow-on 030310Z aircraft fix. Post-analysis revealed that a mid-latitude, short-wave trough passed north of Alice during this time period. The trough extended deep enough into the tropics to weaken the mid-tropospheric ridge. This weakness permitted a southward intrusion of mid-latitude westerlies into Alice's vicinity, temporarily steering her northeastward. As the short-wave trough continued eastward, the subtropical ridge quickly reestablished itself north of Alice producing strong easterly steering flow, temporarily accelerating her from 4 to 10 kt (8 to 19 km/hr) toward the northwest when continued northeast movement was forecast. During this time, decision makers on Eniwetok (also within the Marshall Islands), noting the low forecast confidence stated on prognostic reasoning messages, kept a condition of readiness which paid off.

From the 6th to the 11th, Alice traveled due west. On the 8th, Alice attained 110 kt (57m/sec) intensity and simultaneously accelerated to a speed of 14 kt (26 km/hr) (the fastest observed along track), whereupon she began weakening slowly.

During the 9th, Alice began an unexpected northward movement trend and showed further weakening. Post-analysis of low-level synop-

tic data and satellite imagery (Fig. 3-01-1) indicated that an approaching frontal shear-line was the responsible agent. The shear-line began interacting with Alice while she was southeast of Guam. As Alice neared Guam, radar data from Andersen AFB and aircraft data indicated that Alice's previously well-defined wall cloud became larger and somewhat less organized. Cooler, drier air north of the shear-line was likely responsible for this weakening trend. A weakness in the subtropical ridge vertically above the shear-line apparently allowed for Alice's northward deviation.

The most unusual portion of Alice's track occurred during the final 3 days of Alice's life. Based on interpretation of PE progs, the subtropical ridge was expected to persist and maintain Alice in the easterlies. As a result, the JTWC forecasts (supported by the majority of objective forecast aids) indicated westward movement until 120000Z, 18 hours after Alice had actually begun tracking northwestward. The subtropical ridge weakened in response to a long-wave trough deepening over eastern Asia. Easterly steering currents in Alice's vicinity diminished and veered in direction, permitting a more northward track. Alice reached a secondary intensity maximum of 100 kt (51 m/sec) during this period due to her slowing in speed of movement, the increased absolute vorticity of higher latitudes and good outflow aloft.

By the 13th, Alice turned northeastward and began weakening rapidly. The subtropical ridge was now completely severed and upper-air westerlies were shearing Alice significantly in the vertical. Close proximity of yet another frontal shear-line contributed to further weakening. The biggest surprise, however, came when Alice's low-level circulation turned almost 180 degrees back toward the west at about 131200Z under the influence of strong, low-level easterlies and weakened rapidly in the strong, vertical-shear environment. As a result of vertical decoupling, Alice as a shallow depression, dissipated during the following 12-hour period.

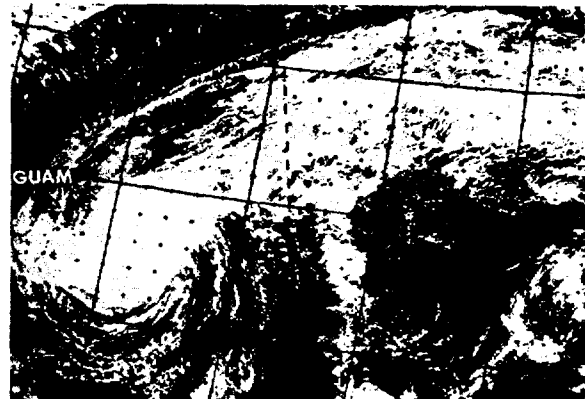
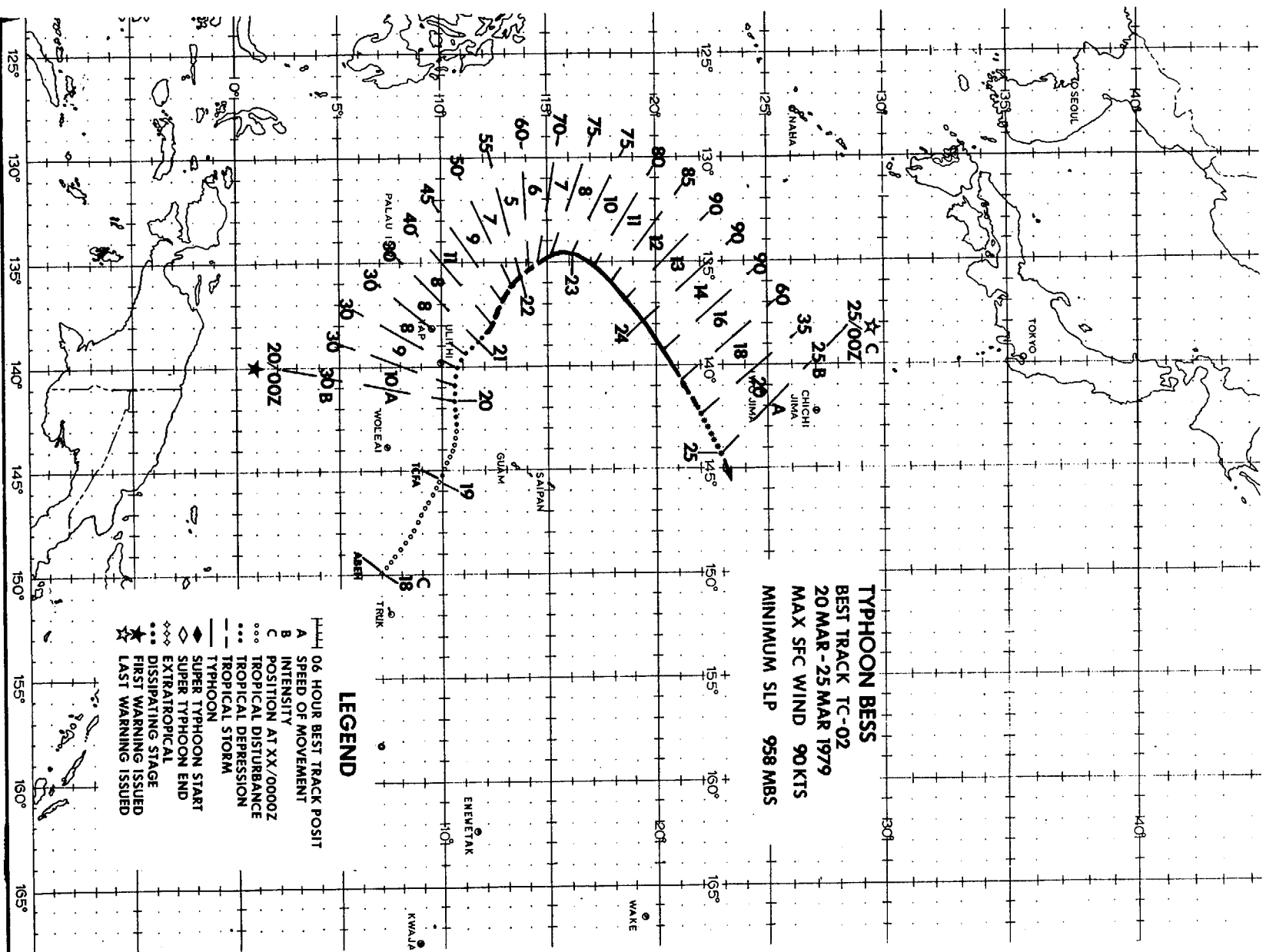


FIGURE 3-01-1. Typhoon Alice merging with the trailing end of a frontal shear-line, 9 January 1979, 0054Z. [DMSP imagery]





Since 1959, only three typhoons have developed over the Western Pacific in March. Of these three, only Bess developed in the last decade with Typhoon Tess developing in 1961 and Typhoon Sally in 1967. Tropical cyclone development in March is usually inhibited by a southward adjustment in the subtropical ridge axis. Although not recognized in advance, Typhoon Bess' development paralleled Typhoon Tess, which developed in the eastern Caroline Islands and reached tropical depression strength near Woleai Atoll. Continuing northwestward between Guam and Yap, both recurved northward near 135E (Fig. 3-02-1) before dissipating north of 20N under the influence of a strong vertical shear.

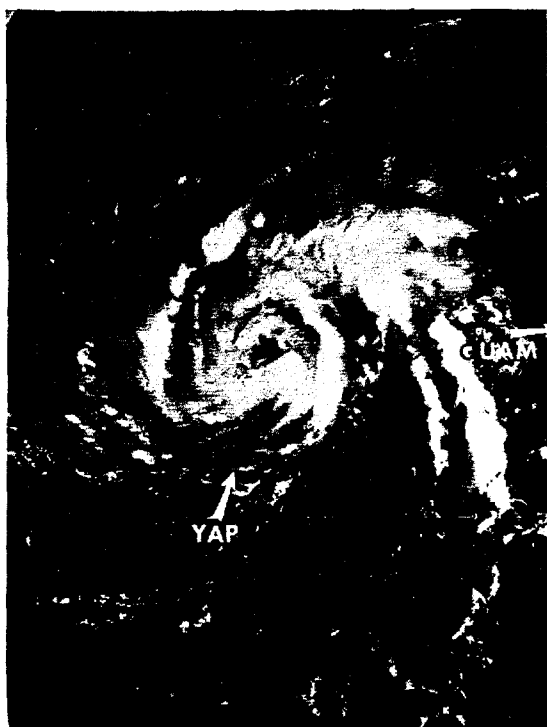


FIGURE 3-02-1. Typhoon Bess tracking northwestward between Guam and Yap at 8 kt (15 km/hr), 21 March 1979, 0103Z. Satellite imagery captured increased organization in the convective banding just prior to Bess reaching tropical storm intensity. (DMSP imagery)

Synoptic data at 160000Z suggested the existence of a weak surface circulation near 3.0N 152.5E at the base of a wave in the easterly flow. Satellite imagery at 160119Z indicated that an ill-defined area of convection existed near the surface circulation. By 161109Z, however, increased upper-level organization suggested development of a weak 200 mb anticyclone (Fig. 3-02-2). Increased curvature in the mid-level convective cloud pattern hinted at the possibility of tropical cyclone formation. As often observed in weak

developing systems, 162207Z satellite imagery showed a significant decrease in the mid- to upper-level convective organization, while the synoptic analysis continued to support a weak circulation southeast of Guam. Continuing to pulsate, the suspect area presented a curious, but intensified upper-level convective pattern on 172151Z and 172333Z satellite imagery. Synoptic analysis at 180000Z indicated that, in addition to the circulation near 3.5N 147.5E, a secondary low had developed on the slow moving wave axis near 7.1N 150.0E and that the earlier ill-defined convection had been associated with these two circulations. As this secondary low tracked northward up the wave axis, increased cyclon-



FIGURE 3-02-2. Infrared imagery of very early development stage of Bess, 16 March 1979, 1109Z. Streamline pattern indicates an upper-level anticyclone. A surface circulation had not yet developed. (DMSP imagery)

ic shear between strong easterly flow north of the wave and weak equatorial westerlies south of the wave caused the northern circulation to become the dominant center as the initial low weakened. Simultaneously, the upper-level anticyclone intensified, producing an excellent outflow signature on 182315Z satellite imagery (Fig. 3-02-3). Although a formation alert was issued based on 182315Z satellite imagery, continued rapid development did not occur as expected. Aircraft data at 200259Z found strong enhanced easterly flow of 20-30 kt (10-15 m/sec) to the northeast, but only weak cyclonic flow to the south and east. Aircraft reports finally confirmed tropical storm strength early on the 21st (Fig. 3-02-4), five days after Bess was initially observed.

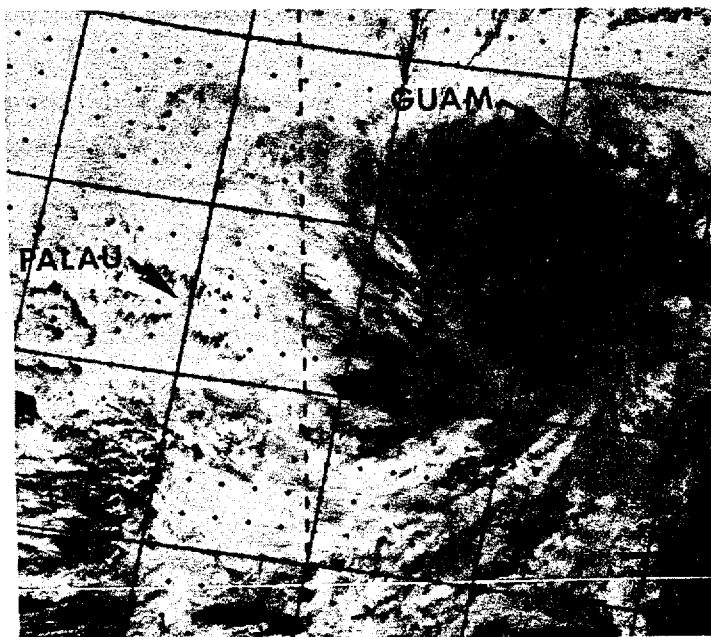


FIGURE 3-02-3. Infrared imagery of Typhoon Bess developing under good upper-level outflow which is visible from the southeast through the northwest, 18 March 1979, 2315Z. (DMSP imagery)

Sea Surface Temperature (SST) plays a vital role in the development and maintenance of tropical cyclones. A study by Charles P. Guard (1979) indicates that tropical cyclones which move over water cooler than 26C are less likely to intensify due to a reduction in latent heat. The study further states that tropical cyclones which develop prior to June intensify up to 10 kt (5 m/sec) after recurvature. This intensification, if experienced, will occur within the 12-24 hour period following recurvature. Typhoon Bess followed this recurvature pattern. The axis of recurvature was crossed at 230000Z. Slow intensification occurred over the next 18 hours with Bess reaching her maximum intensity of 90 kt (46 m/sec) at 231800Z. Bess maintained 90 kt (46 m/sec) for 18 hours and then rapidly weakened, dissipating by 250000Z. SST analyses during 24-27 March (Fig. 3-02-5) indicate that the area in which Bess weakened from 90-60 kt (46-31 m/sec) in a six-hour period corresponds closely to the location of water cooler than 26C. The reduction of latent heat input, coupled with increased vertical shear produced by strong westerlies aloft, literally sheared Bess apart during the final 12-18 hours.



FIGURE 3-02-4. Typhoon Bess just prior to reaching her maximum intensity of 90 kt (46 m/sec), 23 March 1979, 0235Z. Bess displays a large elliptical eye with strong radial cirrus outflow in all directions. (DMSP imagery)

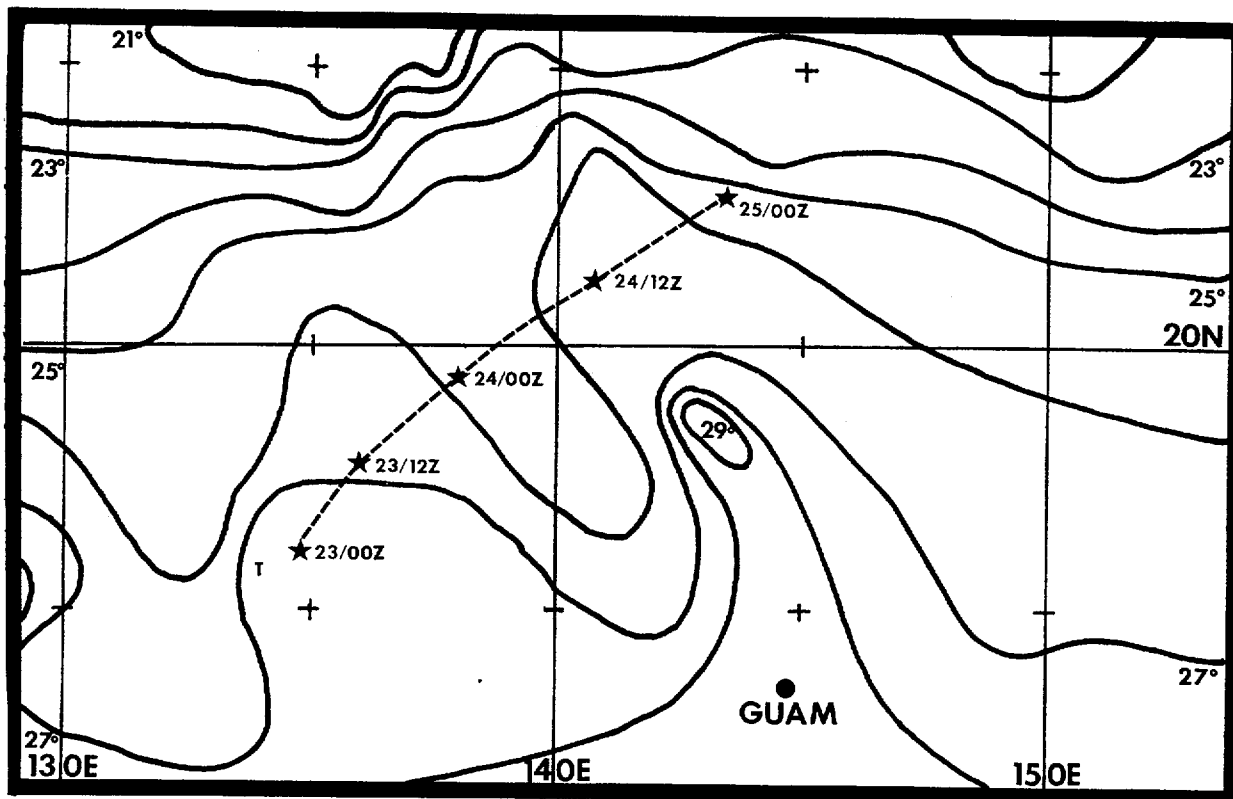
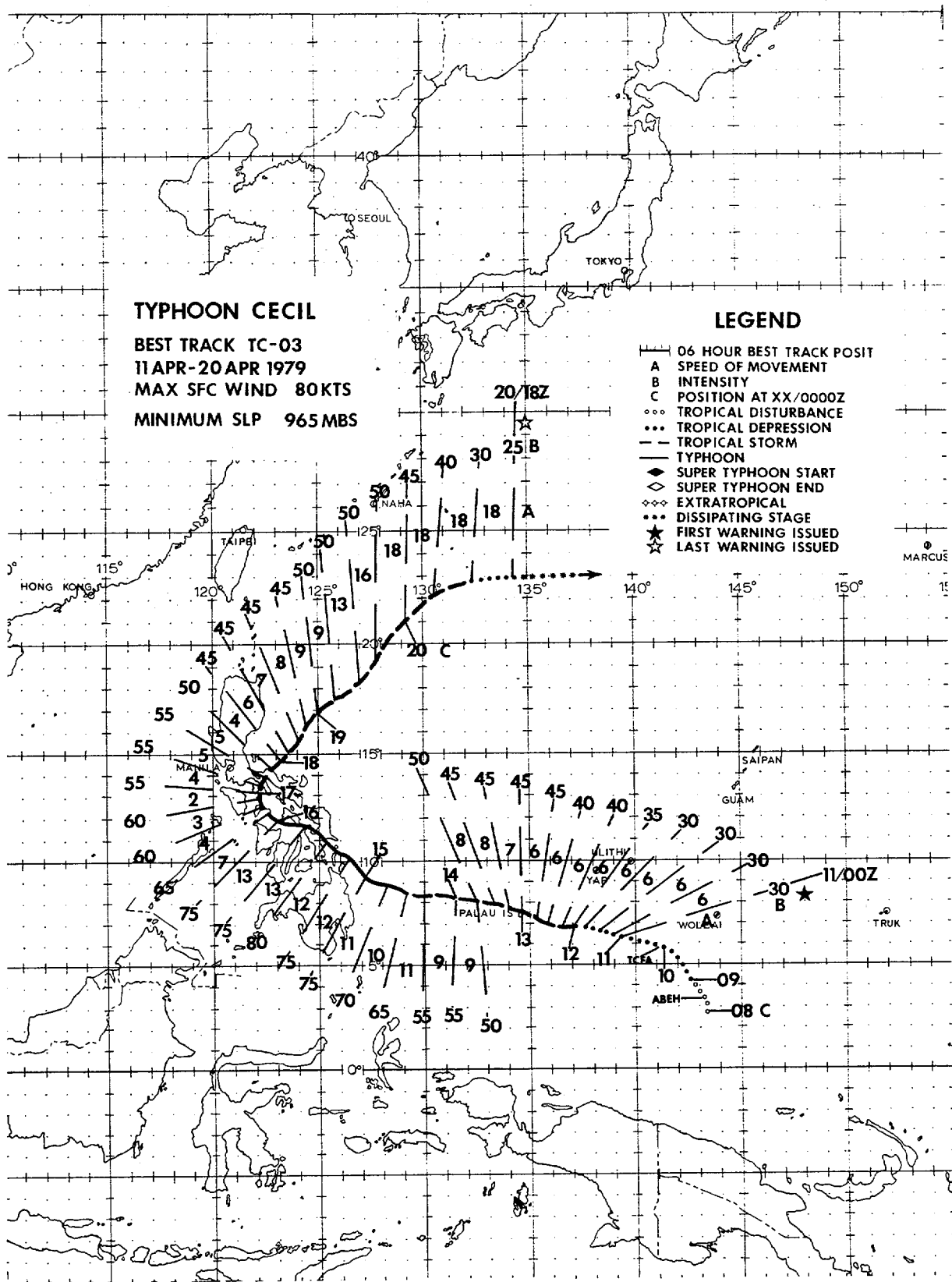


FIGURE 3-02-5. Composite of sea surface temperature analyses from 24-27 March 1979. Northeastward track of Typhoon Bess during dissipation stage is indicated by a dashed line with 12-hour positions.



Typhoon Cecil, the first tropical cyclone of 1979 in the Northwest Pacific given a male name, generated in mid-April from an easterly wave over the Philippine Sea. Cecil was forecast very well while on a climatological west-northwest track toward the central Philippines. Overall, post-analysis statistics showed that mean forecast errors were better than long-term averages. Nevertheless, JTWC warnings failed to forecast the crucial recurvature point in Cecil's track. Was there sufficient evidence to forecast this recurvature 24-48 hours in advance?

Post-analysis showed that recurvature occurred 36 hours after the 151200Z best track position. Satellite imagery (Fig. 3-03-1) located Cecil just south of Samar. At this time, the 500 mb subtropical ridge axis was at 17N with a small high pressure cell located over Northern Luzon. The 500 mb 36-hour PE prog maintained the ridge. Steering techniques based on this synoptic situation indicated westward movement for 72 hours. Analog techniques indicated west-northwestward movement. As a matter of fact, no objective forecast technique indicated recurvature prior to entrance into the South China Sea. The climatological average location of the 500 mb ridge axis is along 15N for April over the Philippines and the climatological recurvature point is 15-17N. Both

synoptic and climatological data indicated a west-northwestward track over the Philippines with recurvature late in the forecast period in the South China Sea as Cecil tracked to the vicinity of 15N. Post-analysis, however, revealed that the ridge axis east of the Philippines abruptly shifted south between 161200Z and 170000Z with westerly winds intruding far to the south over the South China Sea. This pattern shift caused Cecil to recurve much earlier than anticipated. Within 48 hours, Cecil was well east of Luzon (Fig. 3-03-2). The ridge axis shift was the vital piece of information not present in any of the available prognostic tools. Thus, it appears even in post-analysis that forecasting of Cecil's recurvature 36 hours in advance was beyond state-of-the-art capabilities.

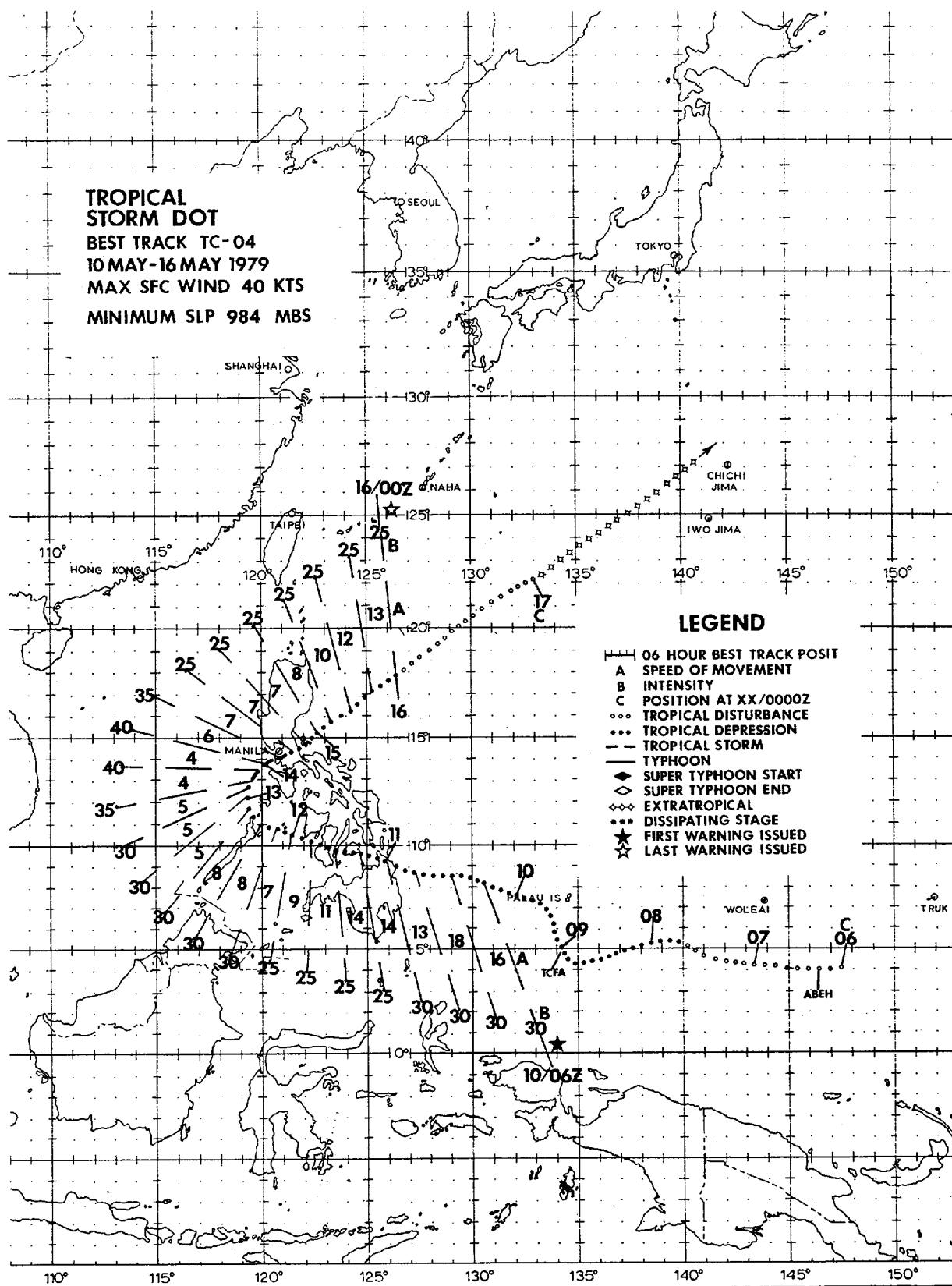


Figure 3-03-1. Infrared imagery of Typhoon Cecil 36 hours prior to recurvature with maximum sustained winds of 80 kt (41 m/sec), 15 April 1979, 1225Z. (DMSP imagery)



FIGURE 3-03-2. Cecil after recurvature with maximum sustained winds of 50 kt (26 m/sec), 19 April 1979, 0014Z. (DMSP imagery)

**TROPICAL  
STORM DOT**  
BEST TRACK TC-04  
10 MAY-16 MAY 1979  
MAX SFC WIND 40 KTS  
MINIMUM SLP 984 MBS



# TROPICAL STORM DOT (04)

Tropical Storm Dot did not reach tropical storm strength prior to landfall on the Philippine Islands (Fig. 3-04-1). Once Dot crossed the islands, tropical storm strength was attained lasting, however, less than 24 hours (Fig. 3-04-2). Dot's development was cut short by the eventual frictional effects of Luzon and increasing vertical wind shear aloft.

TS Dot slowly formed in an area of broad, low-level easterlies, high surface pressures, and strong upper-level shear. The conditions for significant tropical cyclone development were poor while the system existed east of the Philippine Islands. After crossing the Philippines, however, Dot reached tropical storm strength while over the South China Sea.



FIGURE 3-04-1. Tropical Storm Dot at 30 kt (15 m/sec) intensity while over northern Mindanao, 11 May 1979, 0029Z. (DMSP imagery)

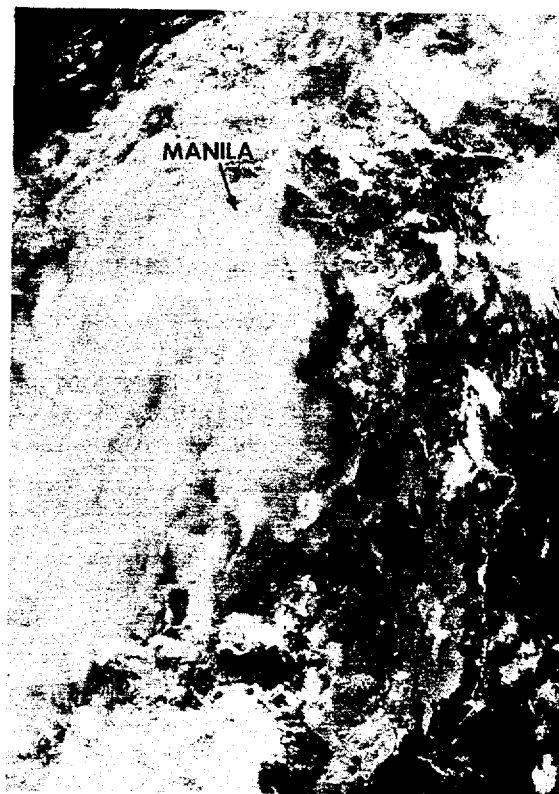


FIGURE 3-04-2. Tropical Storm Dot while recurving toward Manila, 12 May 1979, 2353Z. (DMSP imagery)





Early season disturbances in the South China Sea, as discussed by Ramage (1971), may develop as a result of active monsoon troughs which extend eastward across Southeast Asia into the South China Sea (SCS). During late May, increased convergence in the enhanced southwest monsoon flow produced a significant increase in convection across the SCS, and several weak surface circulations were noted along the monsoon trough between Hainan Island and northern Luzon. Surface/gradient level synoptic analysis at 170000Z confirmed the existence of an elongated pressure trough with several 1005 mb centers. The main circulation, located northeast of the Paracel Islands, was actually north of the main convective area which covered most of the SCS south of the trough. Characteristics of SCS monsoon depressions include: strong enhanced southwesterly flow with light winds near the depression center; large areas of convection associated with convergence in the southwesterly flow with little curvature in towards the center; a relatively flat surface pressure regime of large areal extent; and, a mid-tropospheric cyclonic circulation over the area (Ramage, 1971). These conditions were observed in this area.

Initially, TD 05 drifted southwestward east of the Paracel Islands. By 200000Z a slow, eastward-tracking 500 mb short-wave over central China caused TD 05 to accelerate northeastward. As TD 05 accelerated, increased cyclonic shear at the surface southeast of Taiwan caused the system to transition from a monsoon depression to a tropical depression with a small anticyclonic outflow center evident aloft. (Many SCS monsoon depressions never make this transition, usually dissipating after 3-4 days.) Totally divorced from the monsoon trough, TD 05 tracked eastward through the Bashi Channel and then along the remnants of a weak frontal boundary. TD 05 was not forecast to intensify significantly, but it merged with an extratropical frontal boundary near 22.0N 124.8E and produced an improved satellite signature at 230018Z (Fig. 3-05-1) which included a banding-type eye. (Banding-type eyes are usually characteristic of more intense tropical cyclones.) Synoptic analyses during the life of TD 05 never indicated an intensity above 30 kt (15 m/sec). The lowest pressure recorded was 998 mb measured by a ship close to the circulation center. This pressure equates to approximately 32 kt (17 m/sec) (Atkinson and Holliday, 1975).

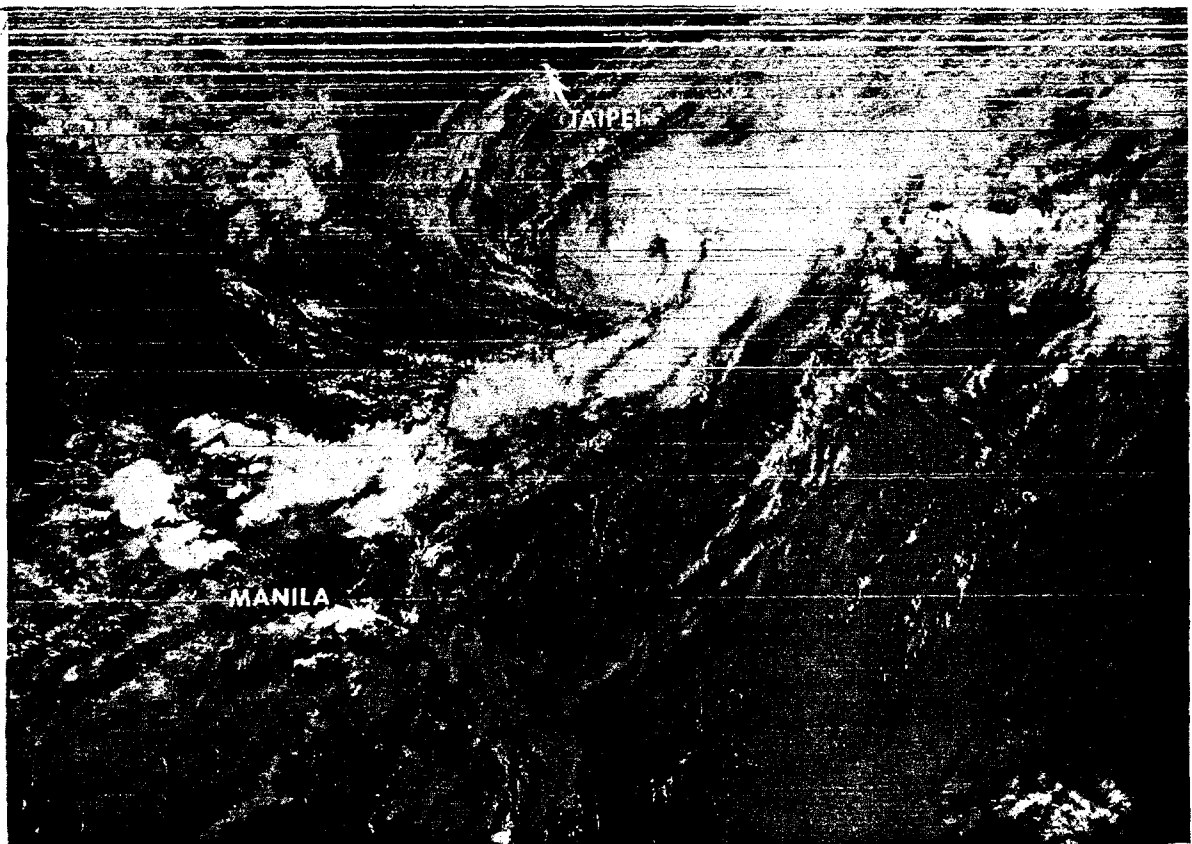
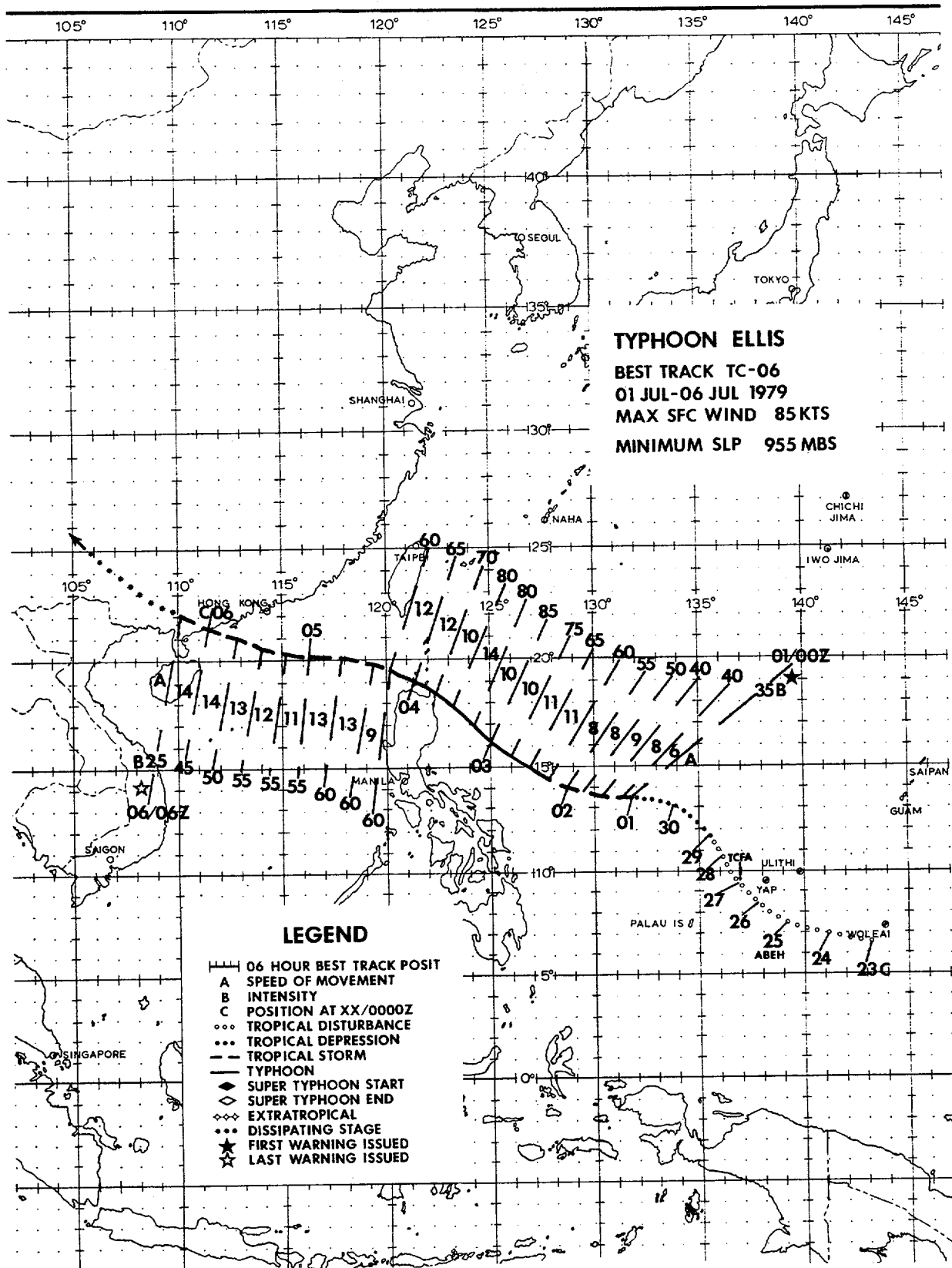


FIGURE 3-05-1. TD 05 at 30 kt (15 m/sec) intensity with banding-type eye moving east-northeastward at 20 kt (37 km/hr), 23 May 1979, 0018Z. (DMSP imagery)



The tropical disturbance, which later became Typhoon Ellis, was first noted on satellite and synoptic data on 25 June 1979. The surface/gradient-level analysis showed that a broad monsoon trough had developed between Guam and the Philippine Islands. At upper-levels, a Tropical Upper Tropospheric Trough (TUTT) was oriented northeast-southwest between the Volcano Islands and the central Philippine Islands. This TUTT allowed excellent upper-level outflow to the northeast and was expected to induce intensification of the tropical disturbance southeast of the TUTT axis. Therefore, a Tropical Cyclone Formation Alert (TCFA) was issued for the area valid at 270000Z. However, significant development did not occur. Reconnaissance aircraft could find only a very broad surface circulation with relatively high surface pressures. The surface circulation drifted under the TUTT and the associated convection was suppressed; development was thereby thwarted. Based on the superposition of the TUTT and the surface circulation and the fact that the overall satellite signature had not improved, the TCFA was cancelled at 282000Z.

The area was closely monitored, and when satellite imagery showed increased convective development and surface data showed decreasing pressures and increasing winds, a second TCFA was issued valid at 300600Z. Subsequent aircraft investigation revealed a minimum sea-level pressure of 1000 mb and surface winds in excess of 35 kt (18 m/sec). Based on this new information, the first warning on TS Ellis was issued at 010000Z July. Ellis was in a favorable position at that time and steady intensification occurred over the next 2 days.

For his entire lifetime, Ellis followed an uncomplicated, classic west-northwest track at near climatological speeds ranging from 9-14 kt (17-26 km/hr). Post-analysis indicates that Ellis was moving under the influence of the east-southeasterly steering flow on the southern edge of the subtropical mid-tropospheric ridge. Ellis' nearly straight track is due primarily to the fact that this ridge did not change in intensity or orientation during the period.

Ellis reached typhoon strength at 021200Z and a maximum intensity of 85 kt (44 m/sec) at 030000Z (Fig. 3-06-1). Continued intensification was anticipated, but a slow weakening trend was actually observed. As with Tropical Storm Faye, this weakening was associated with a drastic change in the upper-level flow pattern.

During Ellis' developing stage, the TUTT was located to the north-northwest and was providing the necessary outflow channel to the northeast. By 020000Z, however, an upper-level anticyclone over central China began to ridge eastward, forcing the TUTT to the northeast. Strong upper-level north-easterly winds associated with this anticyclone began to exert pressure on Ellis, shearing the convective activity to the southwest. Continuing west-northwest in this shearing environment, Ellis weakened steadily. By the time he was in the South China Sea, Ellis had weakened to tropical storm strength and was a completely exposed low-level circulation (Fig. 3-06-2).

With winds of 54 kt (26 m/sec), Ellis made landfall on the Chinese coast at 060000Z, 164 nm (296 km) southwest of Hong Kong and dissipated rapidly over land thereafter.

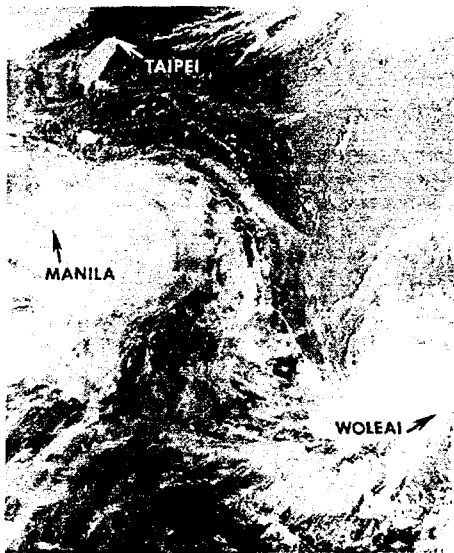


FIGURE 3-06-1. Typhoon Ellis (left) at maximum intensity of 85 kt (44 m/sec), 2 July 1979, 2356Z. TS Faye (right) is developing north of Woleai. (DMSP imagery)

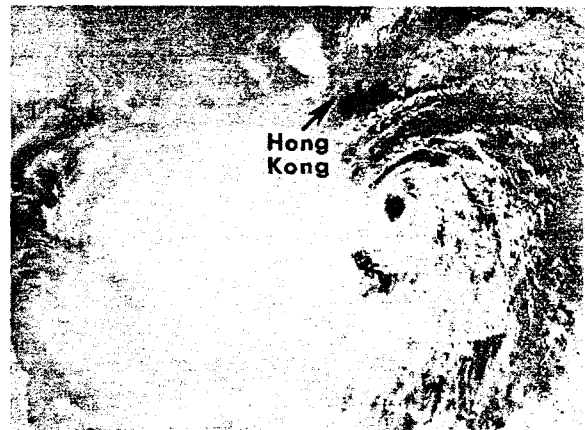
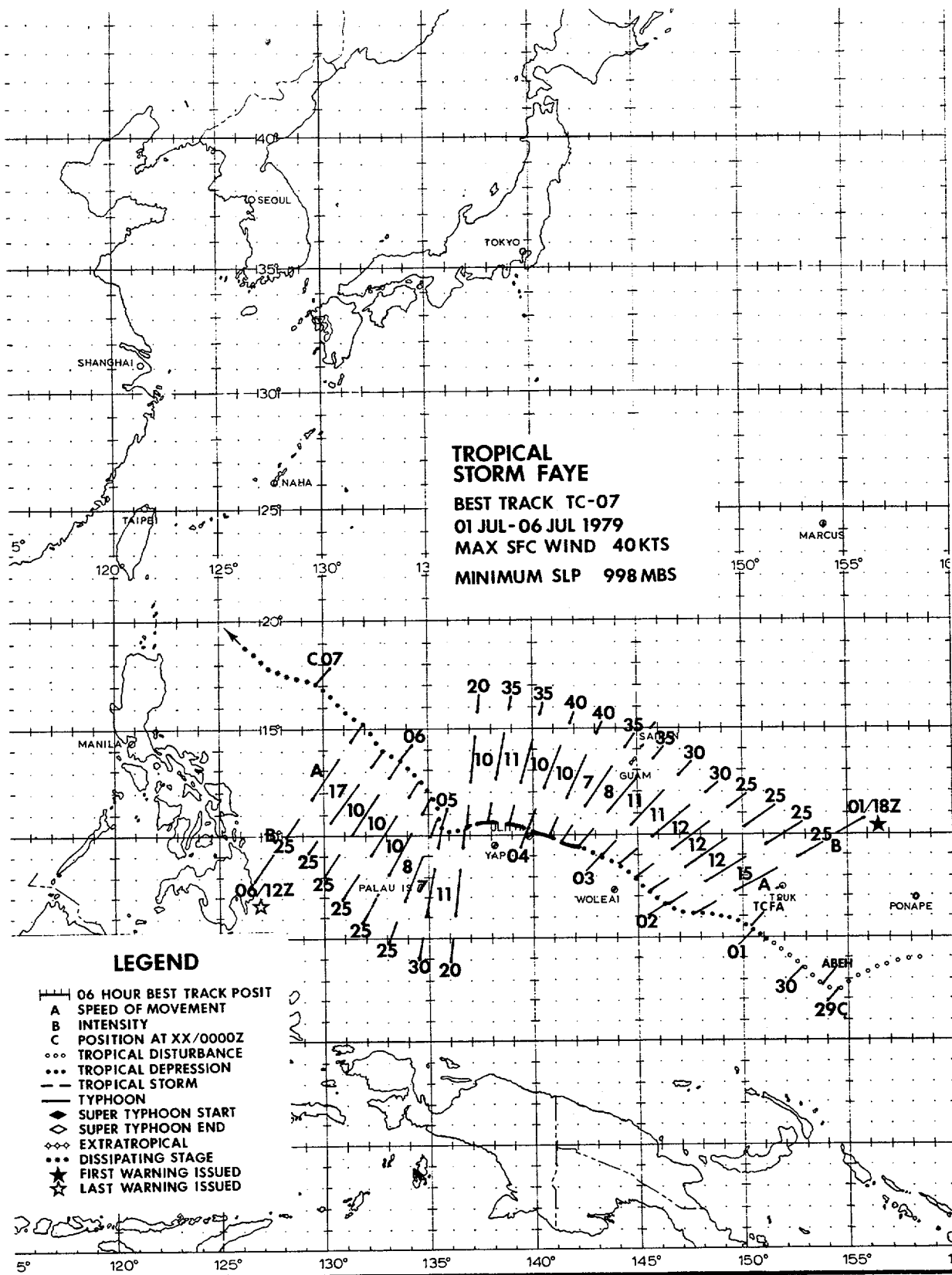


FIGURE 3-06-2. Tropical Storm Ellis as an exposed low-level circulation in the South China Sea, 5 July 1979, 0101Z. (DMSP imagery from Det 5, 1WW, Clark AB, RP)



# TROPICAL STORM FAYE (07)

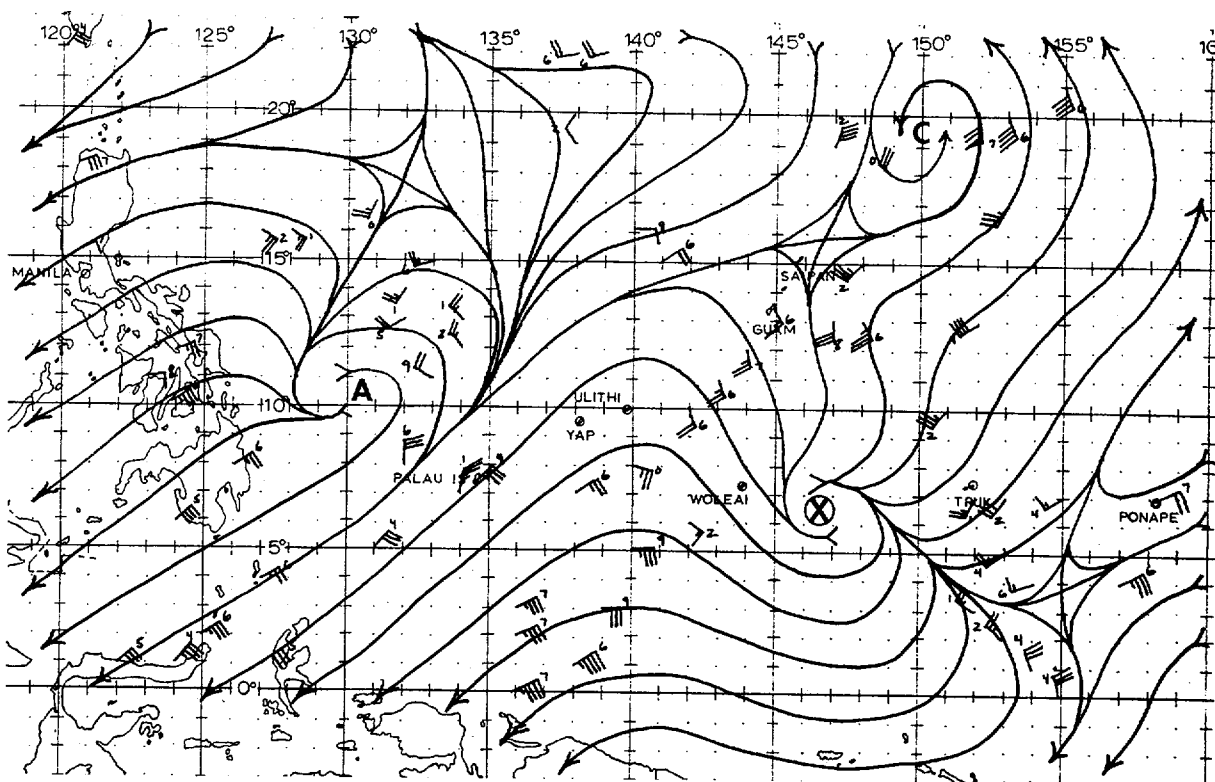


FIGURE 3-07-1. Upper-level streamline analysis at 020000Z July 1979.

Tropical Storm Faye proved a most interesting case study, not because it developed into an intense tropical cyclone, but because typhoon intensity was not attained as forecast.

TD 07 was first analyzed as a closed surface circulation about 800 nm (1482 km) southeast of Guam on the 28th of June. The associated convective activity remained disorganized until 011200Z July. At that time a TUTT cell developed north of the system; thereby providing an excellent upper-level outflow channel to the northeast (Fig. 3-07-1). The wind data plotted in figures 3-07-1, -3 and -5 are a combination of RAOBS, AIREPS and satellite-derived winds for the 250 mb to 150 mb levels.

Diffidence over TD 07 was extensive and well-defined. The satellite signature also showed improved outflow (Fig. 3-07-2), and further intensification was expected.

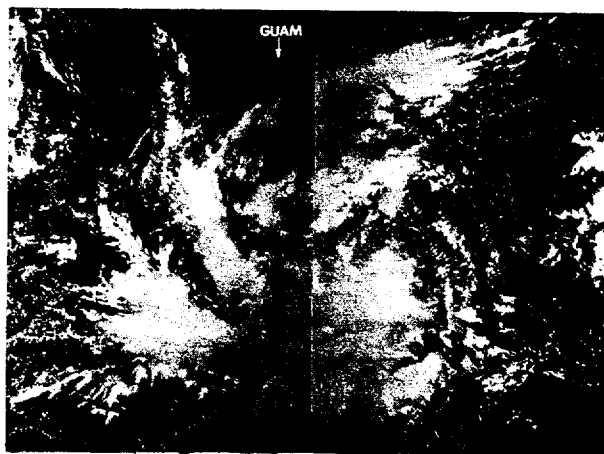


FIGURE 3-07-2. The tropical depression that was to become TS Faye, 02 July 1979, 0022Z. (DMSP imagery)

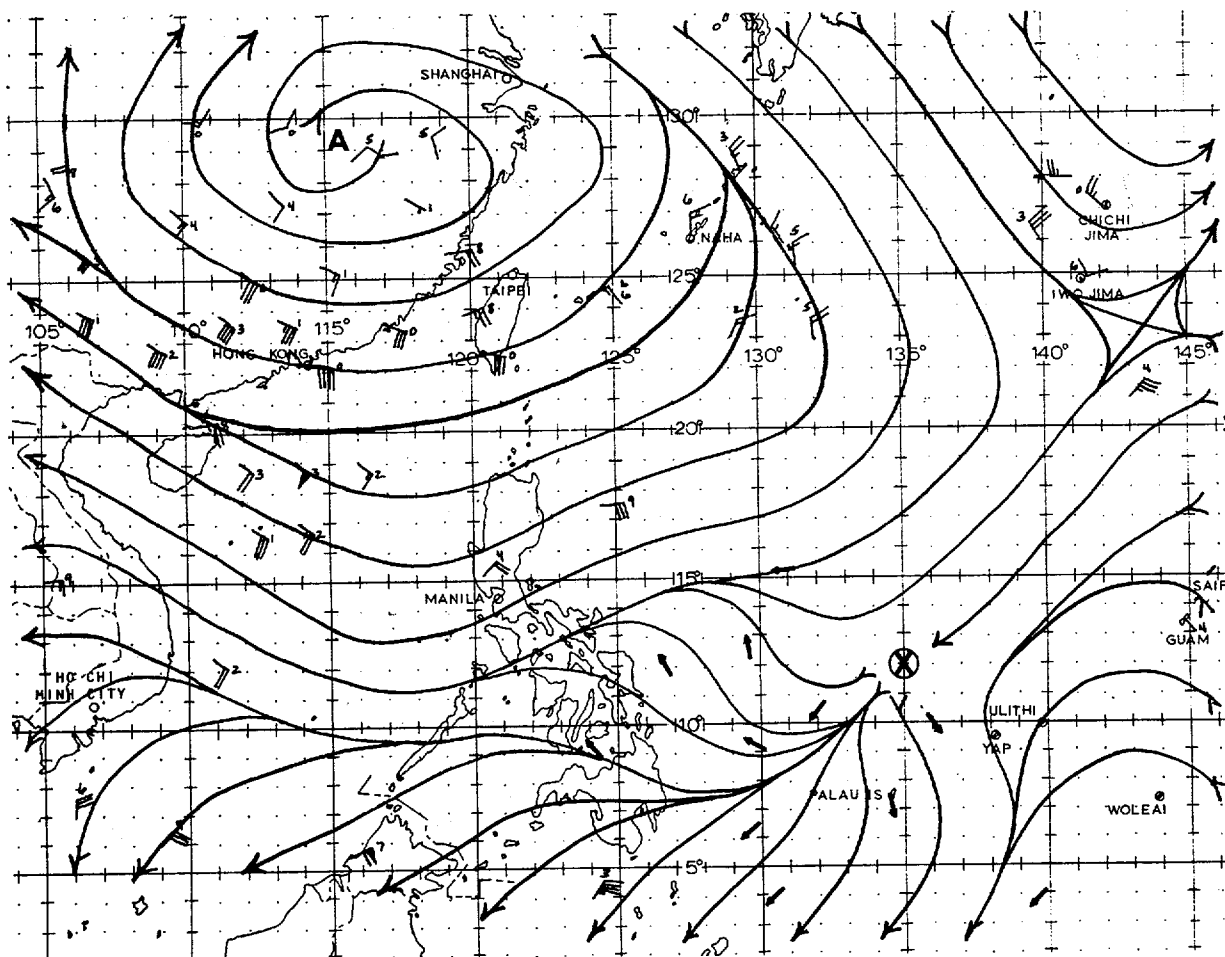


FIGURE 3-07-3. Upper-level streamline analysis at 051200Z July 1979.

The flow pattern over the depression (TD 07) remained favorable for development for the next two days and tropical storm intensity was reached by 031800Z. Continued intensification was still anticipated with typhoon strength forecast within 18 hours.

Instead of intensification, however, Faye weakened. Post-analysis shows that Faye's weakening, and subsequent dissipation, was linked to a radical change in the upper-level flow pattern. Whereas figure 3-07-1 shows a tropical cyclone in excellent position for intensification, figure 3-07-3 shows just the opposite. By 051200Z, a large upper-level anticyclone over China was beginning to build southeastward into the western Pacific toward Faye. Faye's outflow channel to the north became restricted and her low-level circulation center became exposed (Fig. 3-07-4). The mid- to upper-level centers and the associated convection were sheared off to the southwest by increased northeasterly winds at the upper-levels.

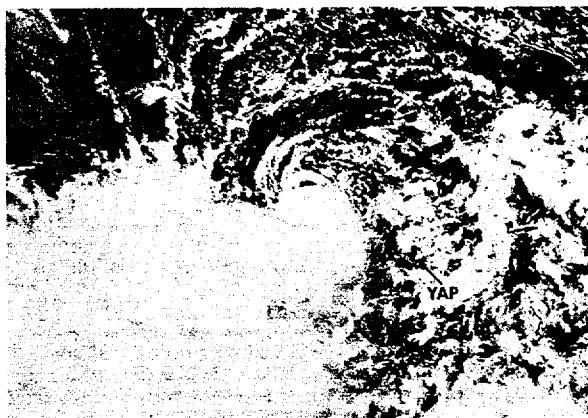


FIGURE 3-07-4. TD 07 (FAYE), 05 July 1979, 1202Z. Strong upper-level northeasterlies have begun to shear off the convection to the southwest. (DMSP imagery, Moonlight Visual)

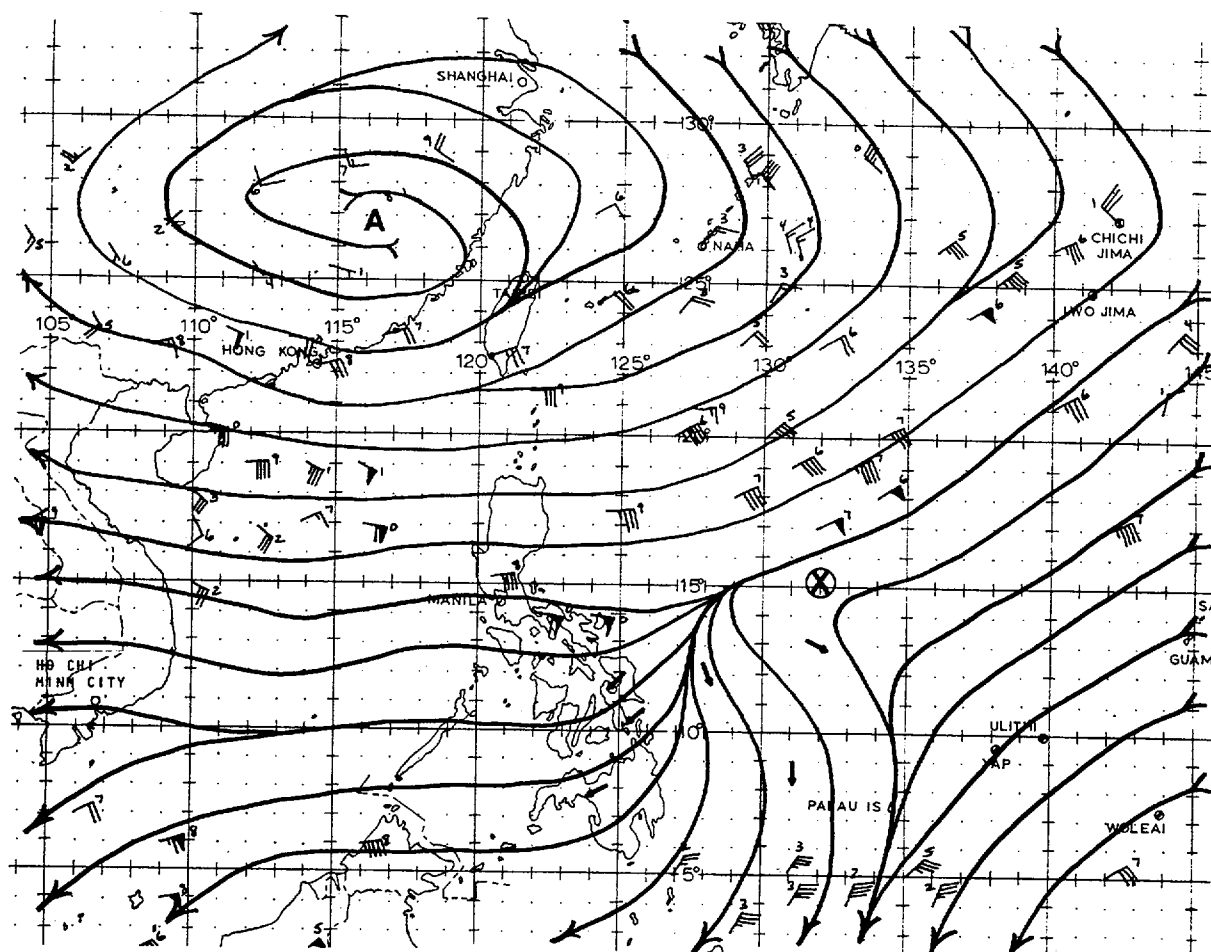


FIGURE 3-07-5. Upper-level streamline analysis at 061200Z July 1979.

Displacement between surface and upper-level centers was observed often during the 1979 season (e.g., see discussions on Hope, Irving, Ellis). Development is usually arrested in this situation, until the system becomes aligned in the vertical. In the case of TS Faye, the upper-level pattern failed to improve. Figure 3-07-5 shows that by 061200Z the upper-level ridge had intruded as far east as Guam and that northeast winds aloft had increased to 50 kt (26 m/sec). At that time, Faye's low-level circulation was fully exposed (Fig. 3-07-6).

This exposed low-level circulation meandered northwestward for two days and eventually dissipated northeast of Luzon.

The short history of Tropical Storm Faye is an excellent example of premature dissipation induced by strong vertical wind shear.

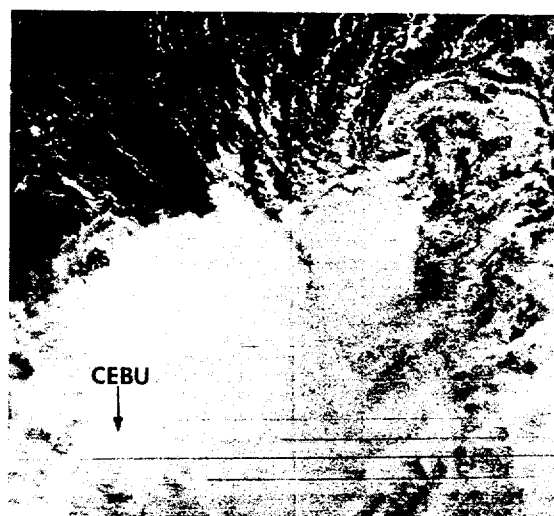
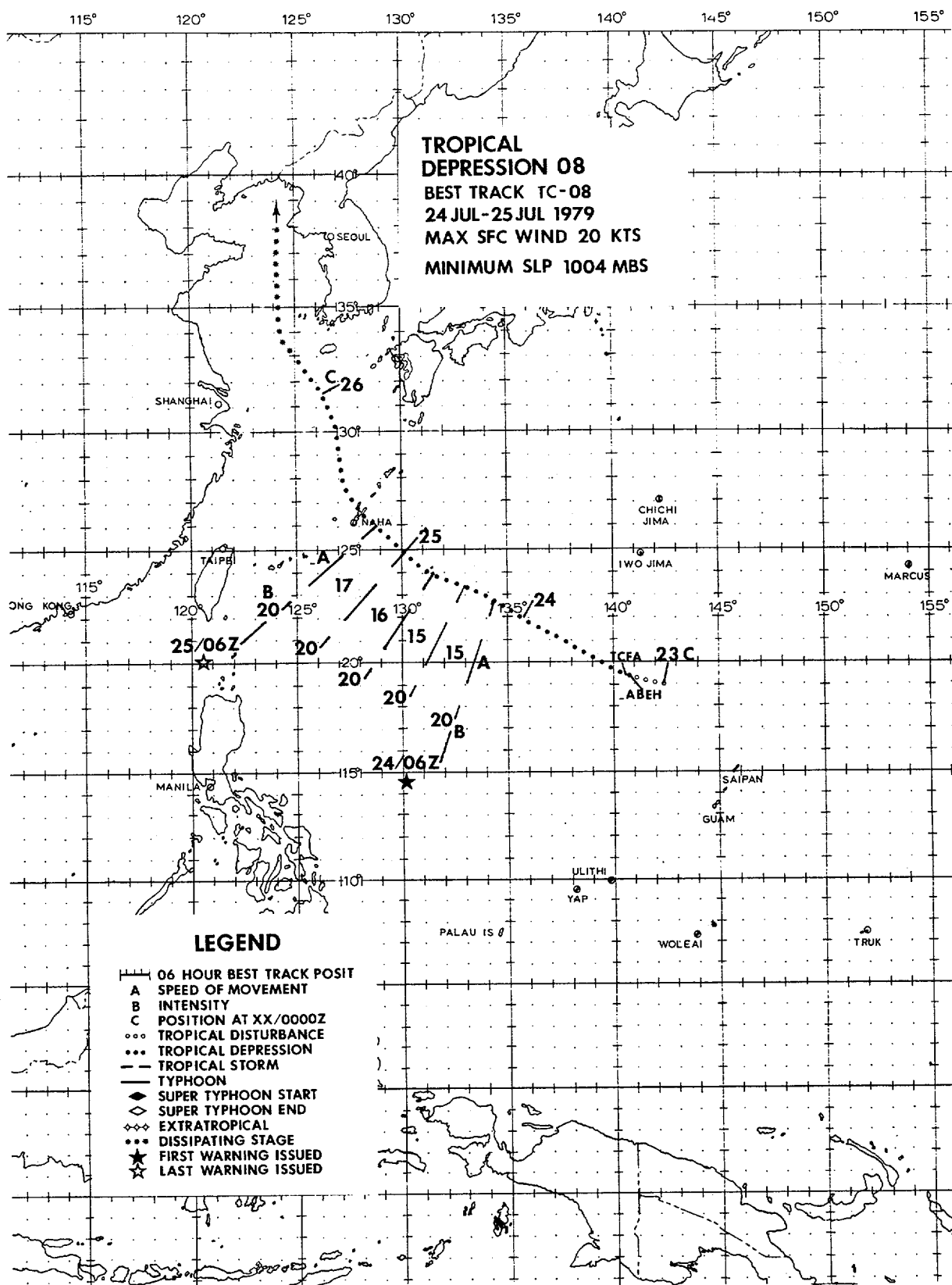


FIGURE 3-07-6. TD 07 (FAVE) is now a fully exposed low-level circulation, 06 July 1979, 1518Z. (DMSP imagery, Moonlight Visual)





# TROPICAL DEPRESSION 08

For the greater part of its life, TD 08 was an exposed low-level circulation with the major convective activity detached to the north of the surface center (Fig. 3-08-1). Aircraft reconnaissance confirmed an exposed surface circulation approximately 100 nm (185 km) south of the convective center at 241016Z.

TD 08 was not expected to intensify to

tropical storm strength as a result of strong vertical shear which began on 231200Z. However, initial warnings were issued based on the forecast track which indicated passage directly over Okinawa.

Post-analysis indicated that the calm-wind center did indeed track over Okinawa with most of the convective activity tracking well north of the island.

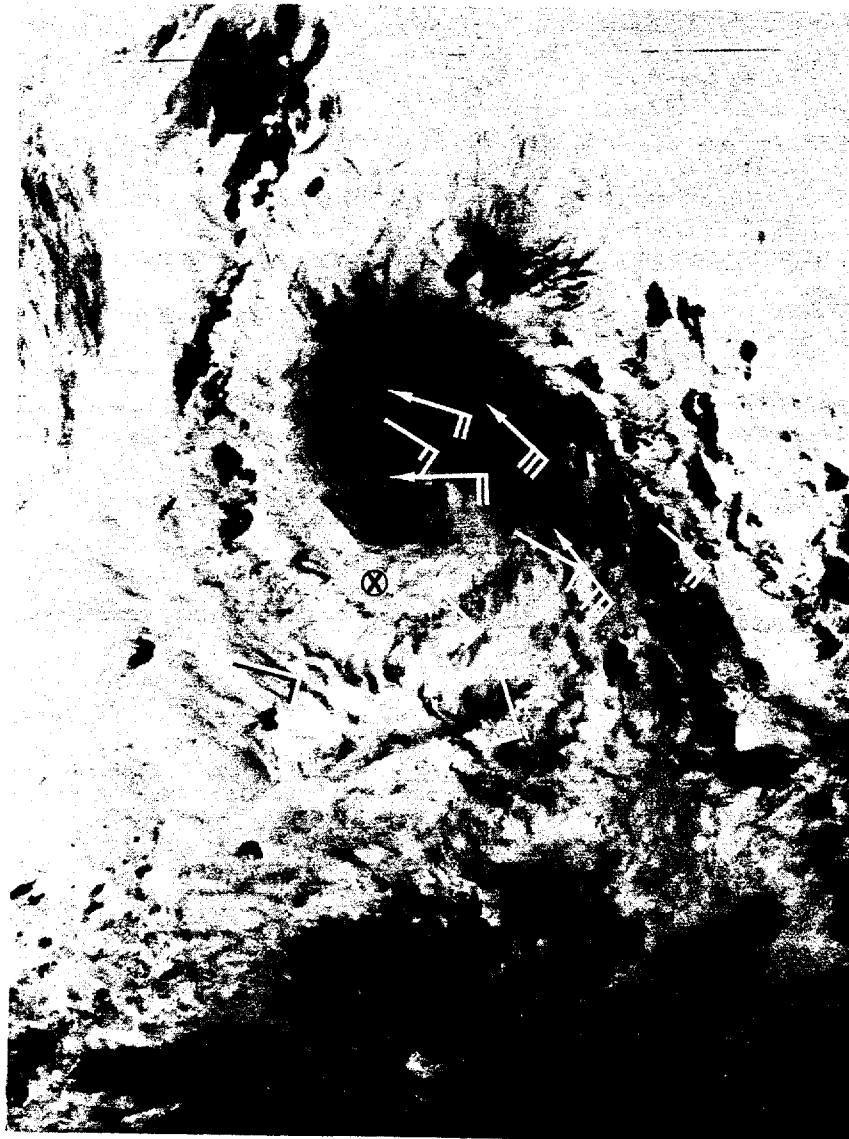
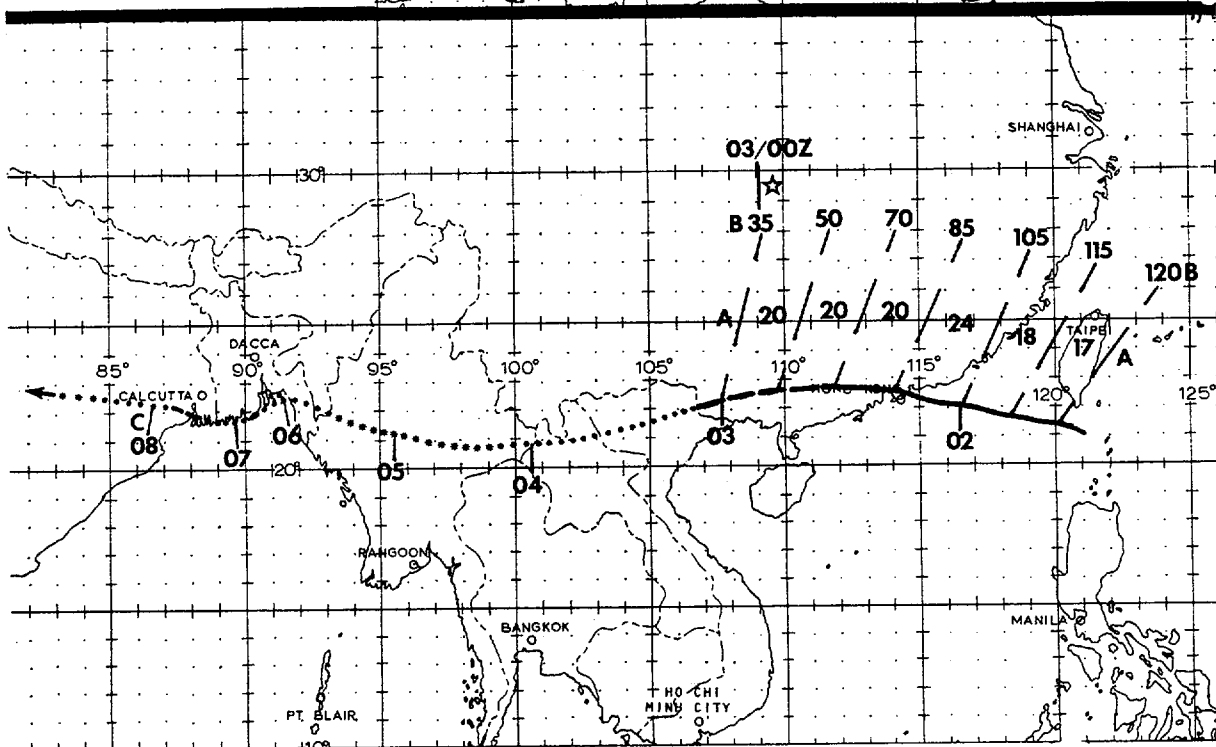
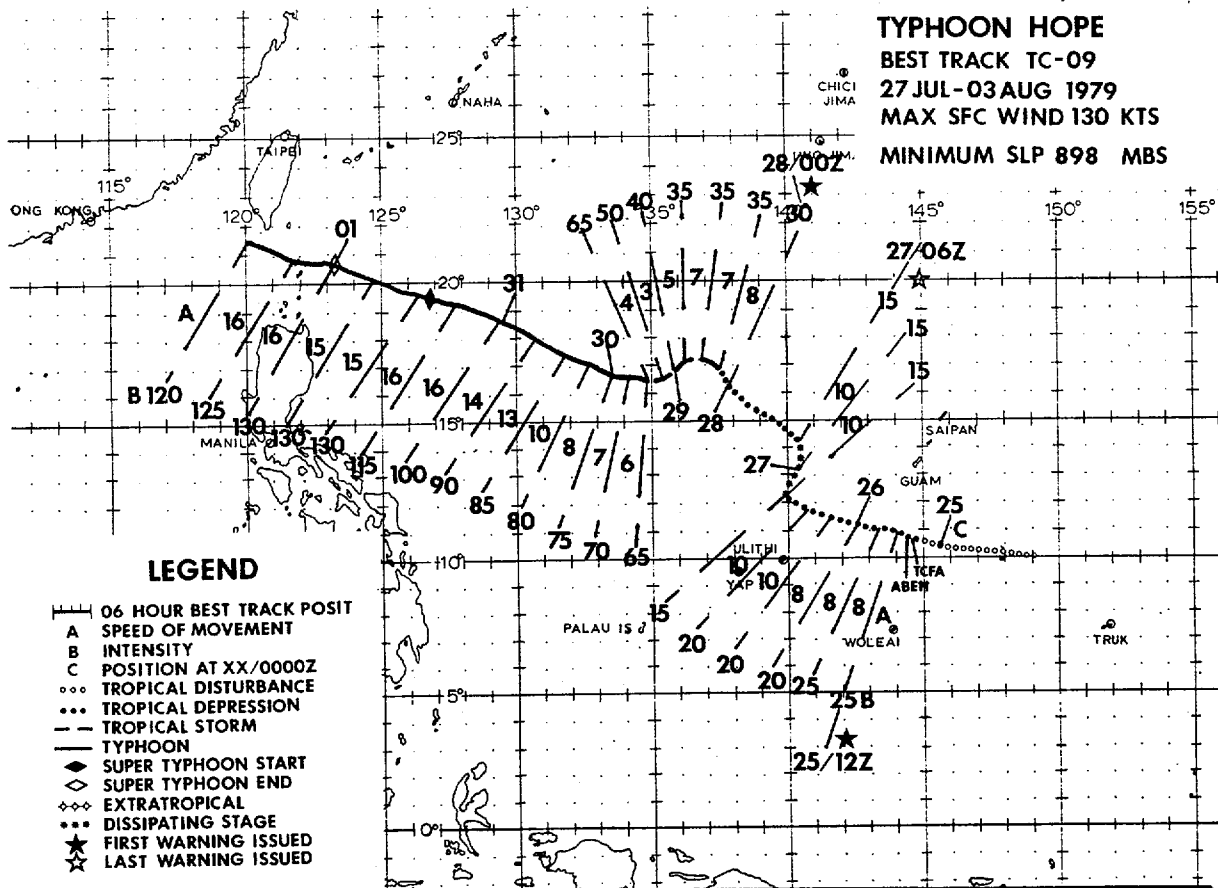


FIGURE 3-08-1. Infrared imagery of TD 08 at maximum intensity of 20 kt (37 m/sec), 24 July 1979, 1244Z. TD 08's 241200Z surface center (⊙) is depicted relative to surface ship reports (—) and 700 mb aircraft reports (←). (DMSP imagery)



# SUPER TYPHOON HOPE (09)

The disturbance which eventually developed into the first super typhoon of 1979 became evident on satellite imagery at 250000Z July as a focal point of cumulus banding. Future intensification was indicated as the disturbance was situated within an area of strong upper-level diffluence associated with the southern periphery of an east-west oriented TUTT. This outflow mechanism aloft, combined with an improved satellite signature, dictated issuance of a Tropical Cyclone Formation Alert at 250751Z; the alert box described an area southwest of Guam. Subsequent aircraft reconnaissance at 250900Z described a cyclonic circulation with wind speeds of 15-25 kt (8-10 m/sec) and a central pressure of 1004 mb centered near 11.1N 144.5E. Based on this aircraft data and the proximity to Guam, the first warning on TD 09 (Hope) was issued at 251200Z.

From the 25th through the 26th of July, while TD 09 (Hope) tracked to the west-northwest; the TUTT axis shifted northward and strong upper-level northeast flow dominated the area. The resultant shear produced by this uni-directional upper-level flow displaced the convective activity to the southwest of the surface circulation, indicating a loss of vertical alignment and subsequent weakening. By 270600Z, the center of the convective activity was displaced 120 nm (222 km) southwest of the low-level circulation center. Surface analyses, at this time, indicated the southwest monsoonal flow was being channeled principally into Tropical Storm Gordon located 750 nm (1389 km) to the northwest of TD 09 (Hope). With further weakening of Hope expected, a final warning was issued at 270451Z advising that the area would be closely monitored for possible

regeneration. Post-analysis showed that from 271200Z through 280000Z, the TUTT weakened with resultant reduced shear over TD 09 (Hope). Conditions for development being improved, reorganization took place and TD 09 began to develop. Unfortunately, the improvement in the surface circulation went unnoticed as it occurred during the night when only infrared satellite imagery, on which low-level clouds are difficult to distinguish, was available. An aircraft investigation on the morning of the 28th reported a surface pressure of 999 mb with 45-50 kt (23-27 m/sec) winds in the heavy convective activity to the southwest of the surface center. A warning was issued at 280221Z indicating the regeneration of TD 09 (Hope).

By 280000Z, Tropical Storm Gordon had moved into the Luzon Straits. Due to the orographic blocking of the Philippine land mass, the majority of the strong southwest monsoonal flow was diverted into Hope. This increased low-level inflow coupled with decreasing upper-level shear resulted in a much improved vertical structure with feederband activity developing in the south; 282052Z aircraft reconnaissance supported this improved organization trend. Post-analysis indicates that TD 09 (Hope) could have been upgraded to tropical storm intensity 12-24 hours prior to the warning upgrade at 290000Z, as 35-45 kt (18-23 m/sec) winds were reported in feederband activity as much as 24 hours earlier (Fig. 3-09-1). By 290920Z, a well-defined eye with a central surface pressure of 972 mb and 65-70 kt (33-36 m/sec) surface winds were reported by aircraft data; the 291200Z warning upgraded Hope to a typhoon.

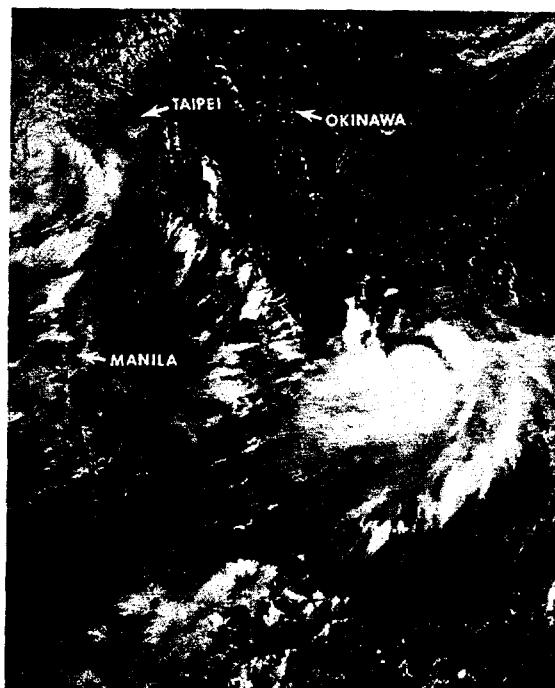


FIGURE 3-09-1. Hope (right) at tropical storm intensity 570 nm (1056 km) northeast of Guam, 29 July 1979, 0219Z. Tropical Storm Gordon (left) is 100 nm (185 km) east of Hong Kong. (DMSP imagery)

The 291200Z 200 mb analysis indicated the TUTT had again established itself north of Hope. Due to the east-west orientation of the TUTT, strong westerly flow along its southern periphery enhanced Hope's upper-level anticyclonic outflow. Aircraft reconnaissance at 292031Z indicated a sharp decrease in surface pressure to 961 mb with the temperature/dewpoint data correlating to an equivalent potential temperature ( $\theta_e$ ) of 359K. An empirically derived forecast aid that relates pressure and  $\theta_e$  indicates that once the traces intersect, rapid intensification can be expected within 18-30 hours (Fig. 3-09-2). The intensification equates to a possible mean pressure decrease of 44 mb and a mean wind speed increase of 50-60 kt (26-30 m/sec). Typhoon Hope verified this study 36 hours after the intersection occurred; reconnaissance aircraft reported a surface pressure of 898 mb and wind speeds of 100-120 kt (51-62 m/sec). By 311200Z, Hope attained super typhoon intensity of 130 kt (67 m/sec) (Fig. 3-09-3).

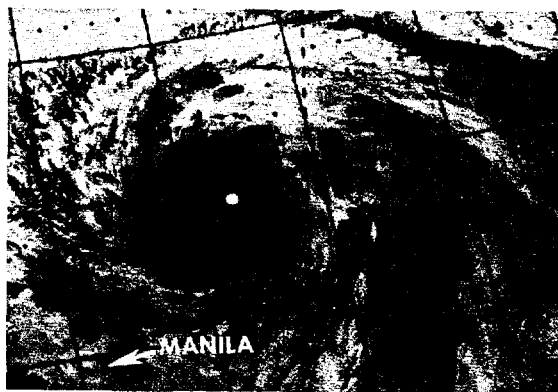


FIGURE 3-09-3. Infrared imagery of Hope just after attaining super typhoon intensity of 130 kt (67 m/sec), 31 July 1979, 1244Z. [DMSP imagery]

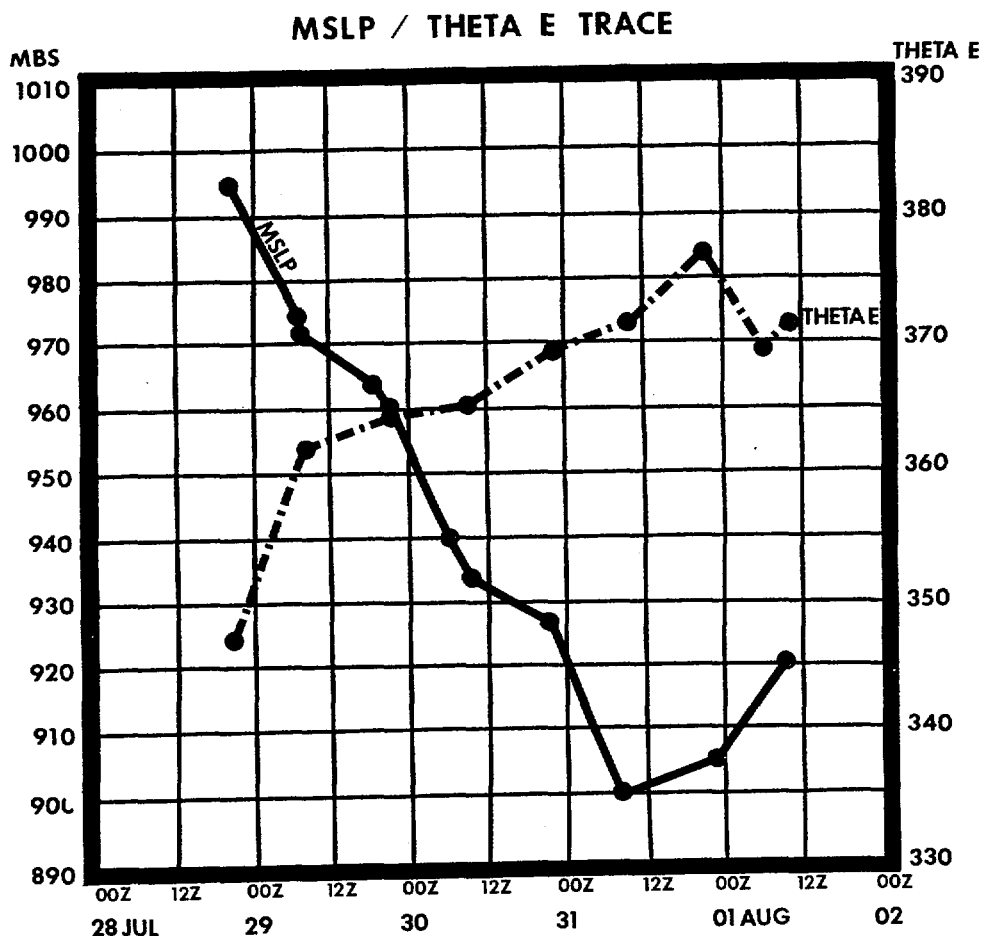


FIGURE 3-09-2. Time cross-section of Hope's minimum sea-level pressure versus equivalent potential temperature (THETA E ( $\theta_e$ )) derived from aircraft reconnaissance.

Hope entered the Luzon Straits approximately 4 days after Tropical Storm Gordon. Hope's compact wind structure and a slight weakening trend were noted as Heng Chun (WMO 46752) on the southern tip of Taiwan reported sustained winds of 40 kt (21 m/sec) with gusts to 86 kt (44 m/sec) at 011000Z as Hope passed 45 nm (83 km) south of the station. Two persons on the Batanes Islands and one person on Taiwan were killed as a result of the torrential rainfall experienced as Hope tracked through the Luzon Straits.

Typhoon Hope made landfall less than 10 nm (19 km) north of Hong Kong at 020530Z (Fig. 3-09-4) with maximum sustained winds of 70 kt (36 m/sec) and gusts to 110 kt (57 m/sec) reported. Figure 3-09-5 is a time sequence of the surface observations received from the Royal Observatory of Hong Kong during Hope's passage. Extensive wind and rain damage, 3 deaths and over 258 injuries were reported. Damage to shipping within Hong Kong harbor was heavy as 17 ships broke their moorings and 8 ships collided.

Subsequent to passage over Hong Kong, Hope moved into southern China and weakened. The final warning was issued at 030111Z downgrading Hope to tropical storm intensity. Hope's uncomplicated northwest track after development into a typhoon resulted in minimal right-angle track errors with her unexpected acceleration accounting for the majority of the discrepancy.

Although weakening considerably during passage over southeast Asia, Hope did maintain a satellite signature and exited into the northern Bay of Bengal 110 nm (204 km) southeast of Dacca, Pakistan at 060500Z.

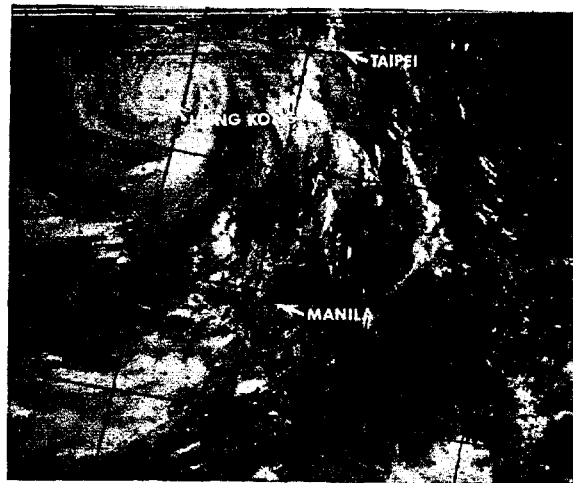
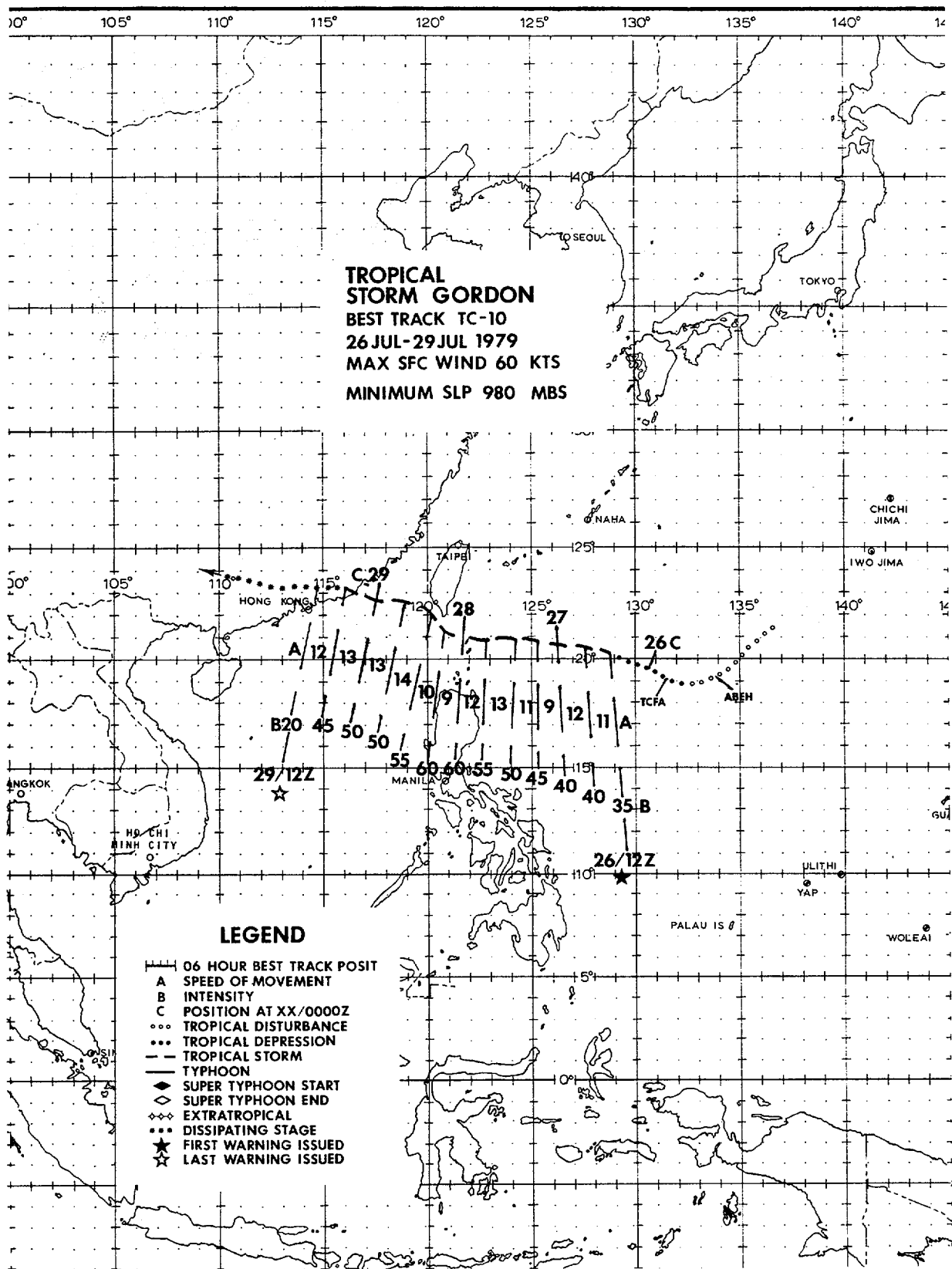


FIGURE 3-09-4. Typhoon Hope at 100 kt (51 m/sec) intensity, 3 hours prior to closest point of approach to Hong Kong, 2 August 1979, 0247Z. (DMSP imagery)

Strengthened once again by pre-existing strong southwest monsoonal flow, Hope reintensified from 070000Z through 071800Z with maximum sustained winds of 35 kt (18 m/sec) reported on 071200Z surface analysis. A tropical cyclone warning was not issued due to Hope's proximity to land and her expected movement into northeastern India within 12 hours. Hope, however, was discussed at length in the Significant Tropical Weather Advisory (ABEH PGTW).

45005 - HONG KONG OBSERVATORY				ST HOPE	DATE: 02 JULY 1979 / TIMES: 01-10Z				
02/01z	02/02z	02/03z	02/04z	02/05z	02/06z	02/07z	02/08z	02/09z	02/10z
991	989	984	978	965	960	976	983	988	992

FIGURE 3-09-5. Hourly surface synoptic observations from the Royal Observatory of Hong Kong (ROHK) during passage of Typhoon Hope.



Gordon, the 10th significant tropical cyclone of 1979, developed in late July in the monsoon trough near 20N-135E and eventually made landfall east-northeast of Hong Kong. A stronger sister, Hope (TD 09), followed Gordon several days later on a similar track into Hong Kong. Note that TD 09 (Hope) and TD 10 (Gordon) are alphabetically out of sequence because TD 10 was upgraded to tropical storm stage before TD 09.

Post-analysis revealed that Gordon reached tropical storm intensity at the time of the first warning. CINCPACINST 3140.1N, section 2.5.1., paragraph b states that warnings will be issued when "maximum sustained wind speeds are forecast to increase to 34 or more knots within 48 hours." In this case, there was no lead time between the first warning and tropical storm stage. Figures 3-10-1 and 3-10-2 illustrate why this occurred. TD 10 developed rapidly within the 22-hour time period between these figures. Synoptic data indicated increasing southwest monsoon flow into the area during this period; yet no definitive surface circulation could be located. The most significant finding of the post-analysis was that Gordon could not be traced back 48 hours prior to the first warning from available synoptic and satellite data, and, therefore, falls into the category of a rapid developing system.

Gordon's track took an unexpected jog northwestward while passing south of Taiwan (Fig. 3-10-3). (Typhoon Hope took a similar, but less pronounced, jog.) This northward adjustment is historically evident from tropical cyclones that pass south of Taiwan. The influence of Taiwan's high mountain range is thought to be responsible. As tropical cyclones pass south of Taiwan, they induce lee-side troughing west of the mountains over the Formosa Strait and track northwestward in response.

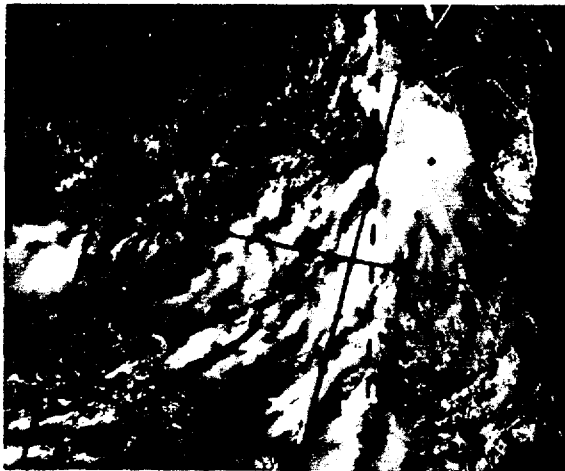


FIGURE 3-10-1. Tropical Storm Gordon in its infancy 4 hours prior to being discussed on the Significant Tropical Weather Advisory (ABEH PGTW), 25 July 1979, 0151Z. (DMSP imagery)

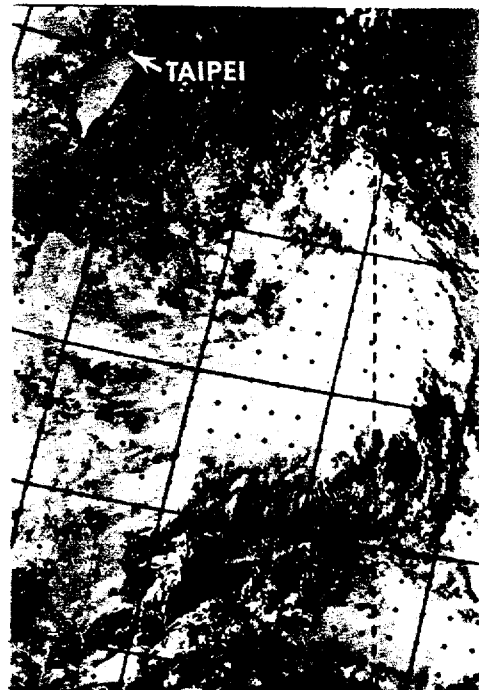
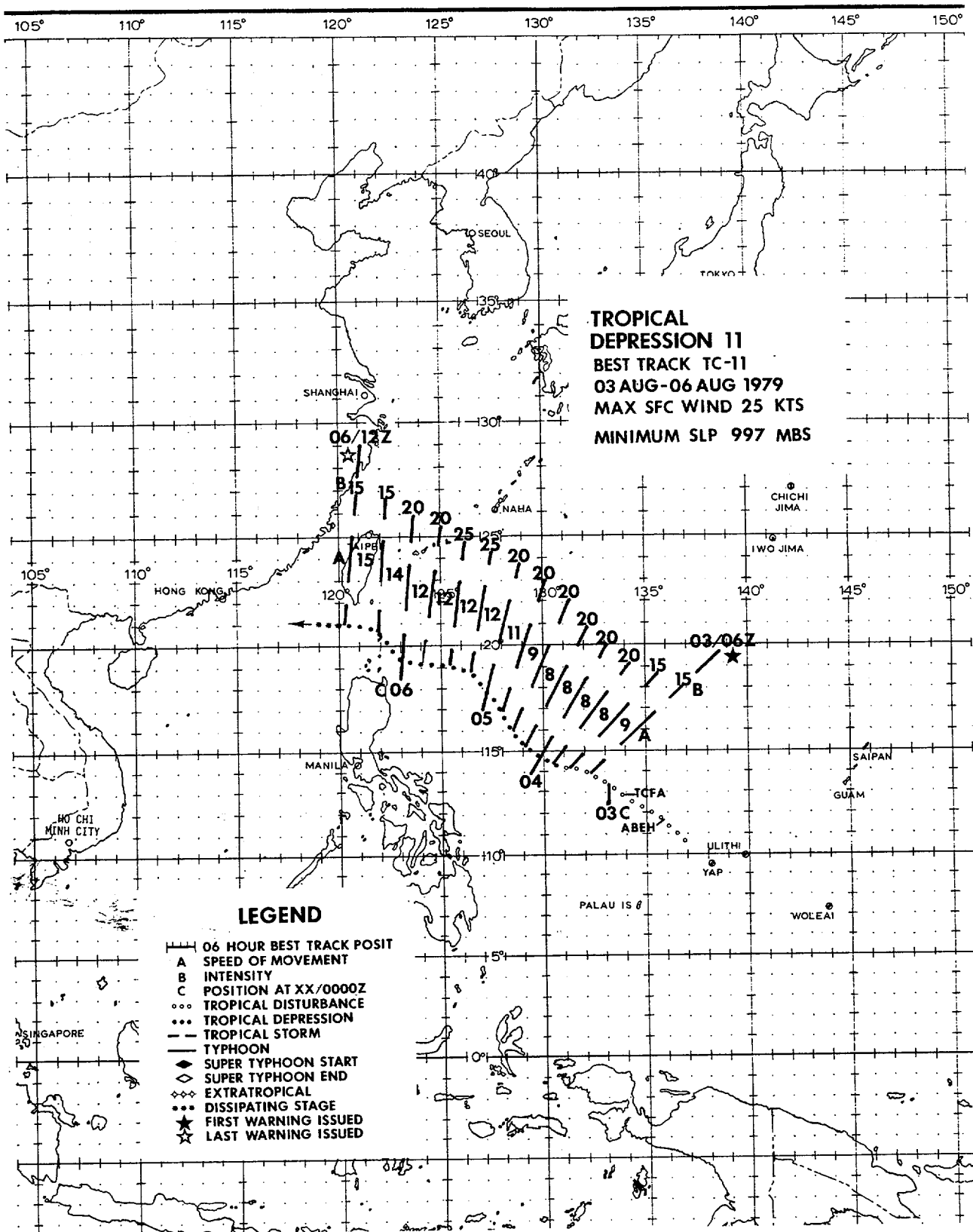


FIGURE 3-10-2. Tropical Storm Gordon 22 hours after Figure 3-10-1 showing increased development, 25 July 1979, 2350Z. A Tropical Cyclone Formation Alert was issued 6 hours prior to this time. (DMSP imagery)



FIGURE 3-10-3. Kaohsiung radar presentation of Gordon at 282103Z after passing south of Taiwan. (Photograph courtesy of the Central Weather Bureau, Taipei, Taiwan.)





TROPICAL DEPRESSION 11

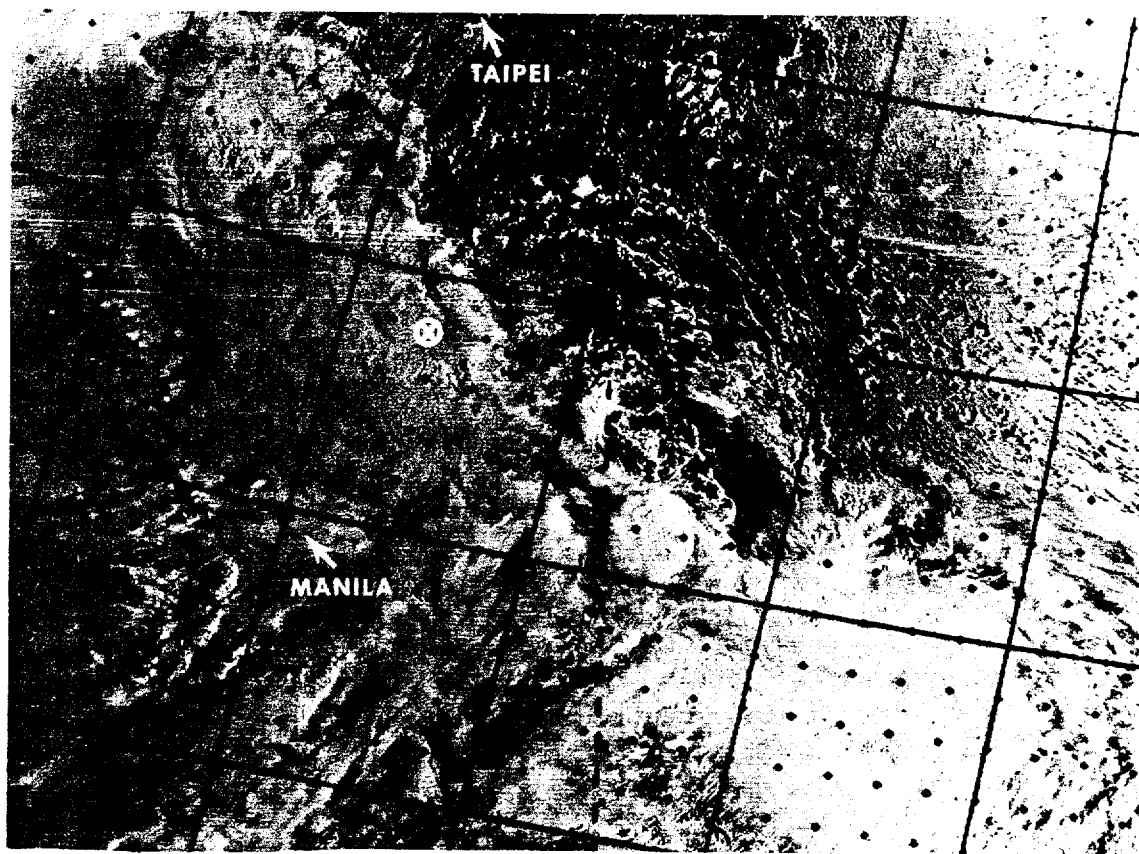
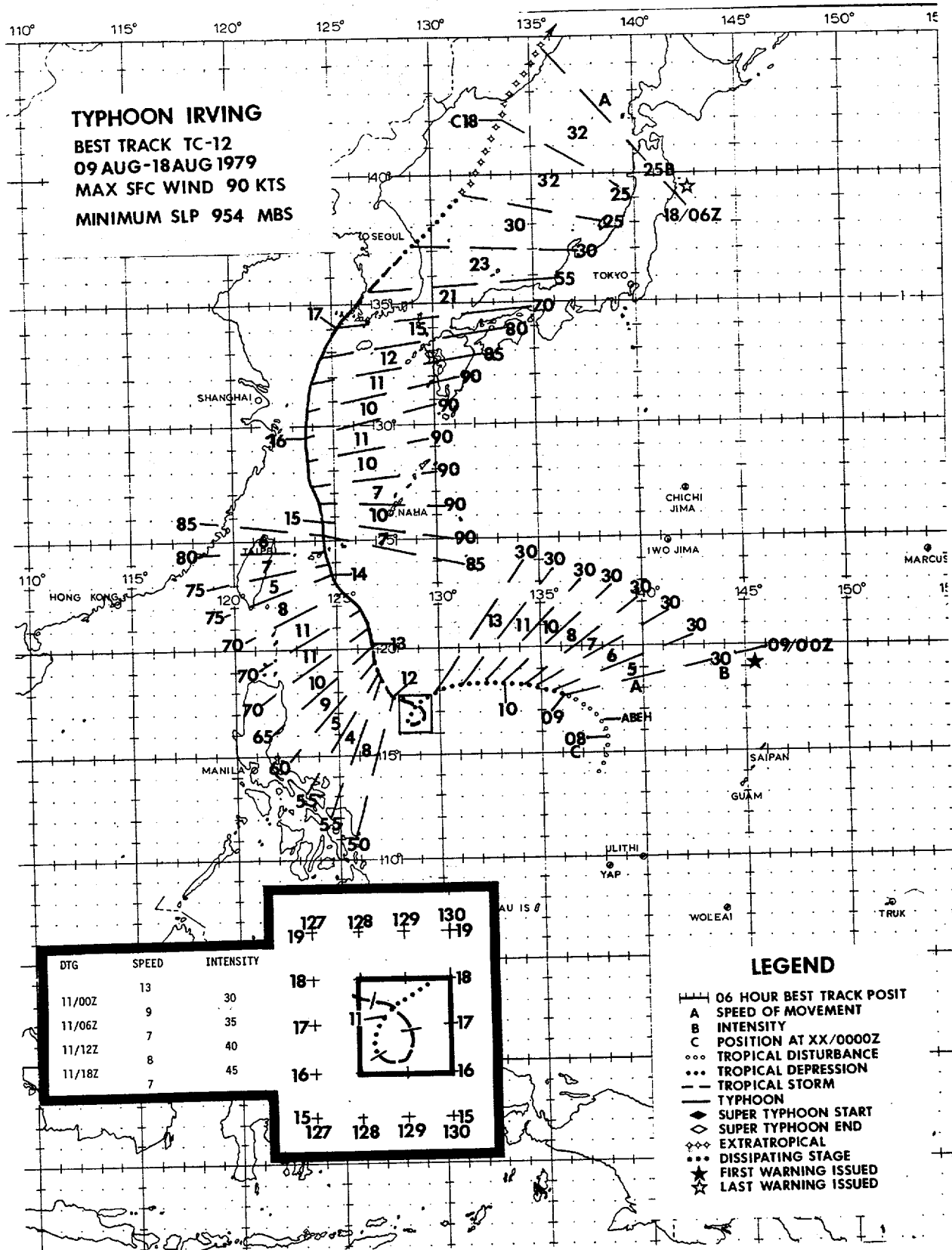


FIGURE 3-11-1. Tropical Depression 11 at 20 kt (10 m/sec) intensity, 5 August 1979, 2153Z. The TD symbol (⊙) is superimposed at location of surface circulation center as determined by aircraft reconnaissance at 052222Z. Considerable vertical shear existed over the system and was the reason that it did not develop into tropical storm strength. (DMSP imagery)



Surges in the southwest monsoon frequent the western North Pacific during the early tropical cyclone season and produce widespread convection from the Malay Peninsula to as far east as Guam. During the same period, the 500 mb monsoon trough fluctuates eastward across the South China Sea (SCS) and occasionally into the Philippine Sea. By late July 1979, an eastward extension of the mid-level monsoon trough was the main synoptic feature west of Guam. The 500 mb trough axis extended along 15N from northern Vietnam through the central SCS and then eastward into a quasi-stationary low pressure center over the Philippine Sea.

On 7 August at 1200Z, a developing surface circulation was observed at the eastern end of the monsoon trough near 14.1N 137.7E. This weak circulation tracked cyclonically around the eastern periphery of the broad 500 mb low pressure center in the Philippine Sea. Taking on the characteristics of a monsoon depression (Ramage, 1971), Irving was described in aircraft reconnaissance data received from 9-11 August as a weak depression with poor vertical alignment and maximum surface winds located 150 to 180 nm (278 to 333 km) west of the surface center. At this stage, Irving displayed an

exposed low-level circulation in satellite imagery with maximum convection located to the west of the surface center (Fig. 3-12-1). Ship synoptic data during the same period indicated that 25-35 kt (13-18 m/sec) winds extended outward 120 nm (222 km) south of the surface center.

By the 11th, the monsoon surge had weakened and receded westward, leaving a cut-off 500 mb low over the Philippine Sea in the vicinity of Irving's surface circulation. Irving executed a small, tight cyclonic loop on the 11th. During the loop, vertical alignment between the surface and the 500 mb center improved, and Irving intensified to tropical storm intensity. Simultaneously, a break developed in the 500 mb subtropical ridge to the north, and Irving tracked north-northwestward towards the Ryukyu Islands while intensifying further to typhoon strength. Although originally forecast to recurve south of Japan, strengthening of the 500 mb ridge southeast of Japan caused Typhoon Irving to track over the western East China Sea and accelerate north-northeastward across Korea before merging with an extratropical frontal boundary north of Japan.

Although not a spectacular typhoon, Irving's apparent sinusoidal motion, unusually large wind radii, failure to rapidly deepen and damage to southern Korea are noteworthy. Sinusoidal motion of tropical cyclones has been observed for many years, especially when short-term movements are observed by accurate fix platforms such as land radar (Fig. 3-12-2) and reconnaissance aircraft. Sinusoidal motion was observed from 131600Z to 151800Z as Irving tracked north-northwestward through the East China Sea. Radar reports from the Ryukyu Islands

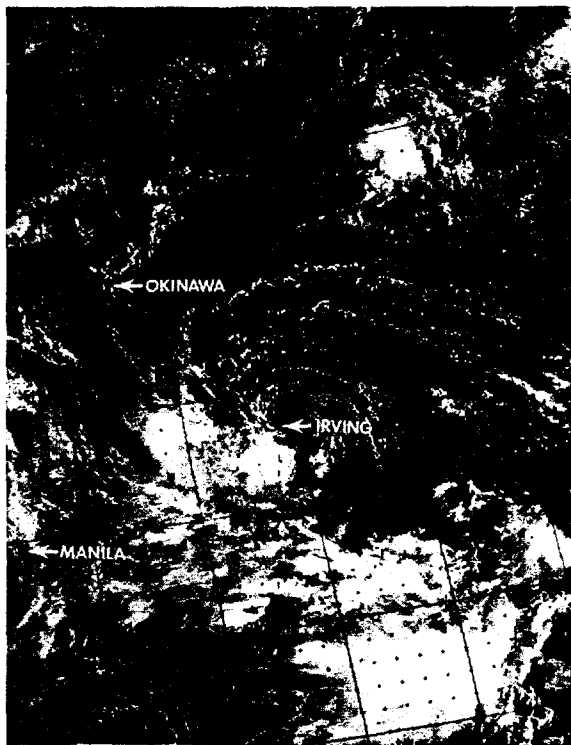


FIGURE 3-12-1. Typhoon Irving as a weak tropical depression with an exposed low-level circulation, 10 August 1979, 0126Z. Prior to intensification, aircraft reconnaissance consistently observed the maximum convection to the west of the surface center. [DMSP imagery]

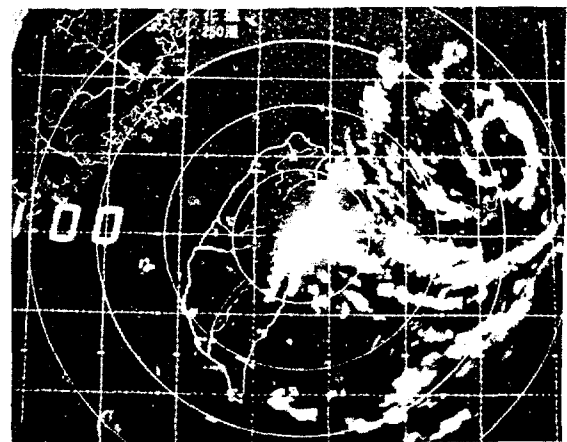


FIGURE 3-12-2. Typhoon Irving as seen by the radar at Haulien, Taiwan. Irving tracked north-northwestward across the southern Ryukyu Islands and was accurately tracked by eight radar sites, 14 August 1979, 1700Z. [Photograph courtesy of the Central Weather Bureau, Taipei, Taiwan]

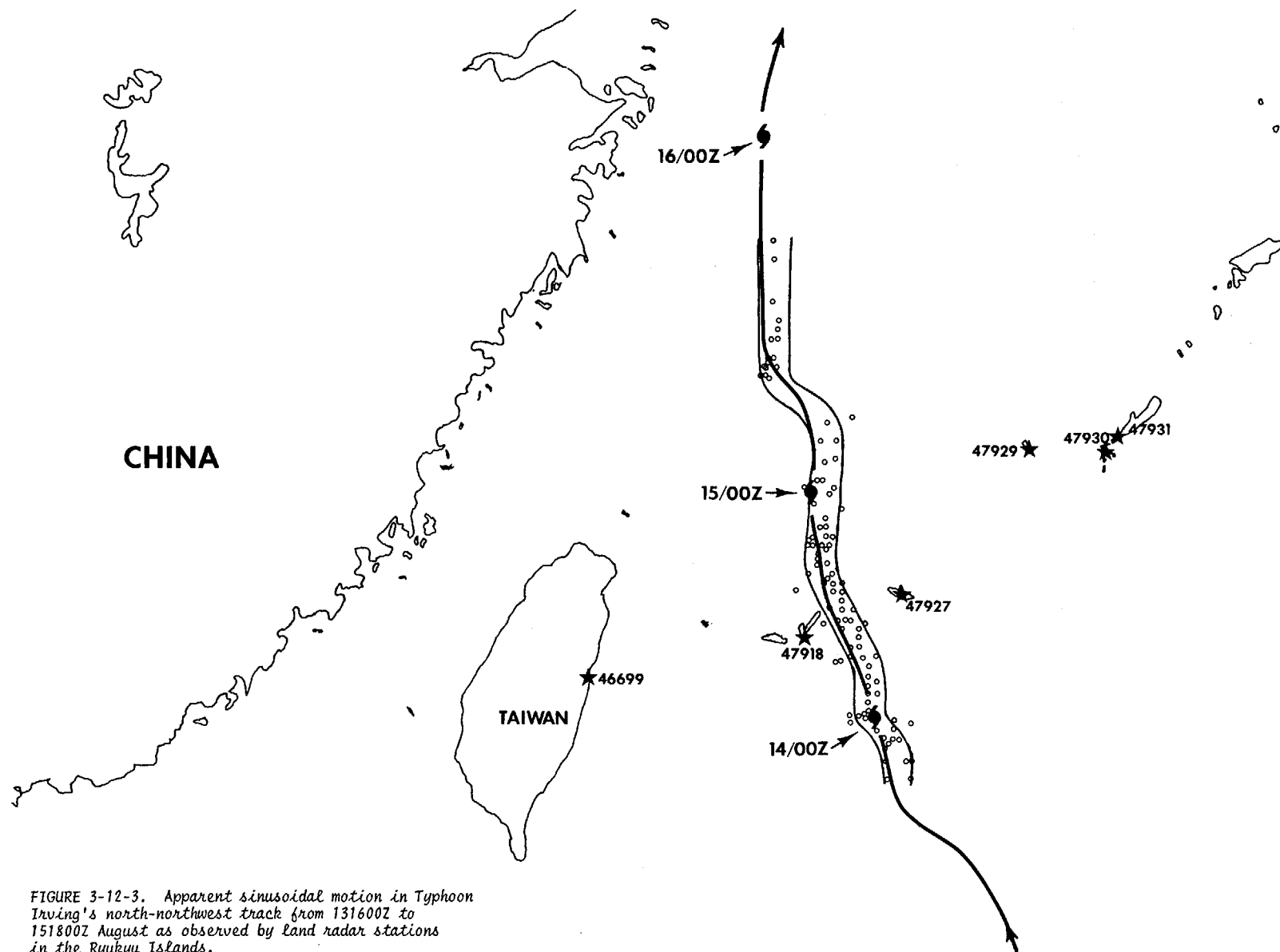


FIGURE 3-12-3. Apparent sinusoidal motion in Typhoon Irving's north-northwest track from 131600Z to 151800Z August as observed by land radar stations in the Ryukyu Islands.

clearly indicate that Irving oscillated about an overall north-northwest track (Fig. 3-12-3).

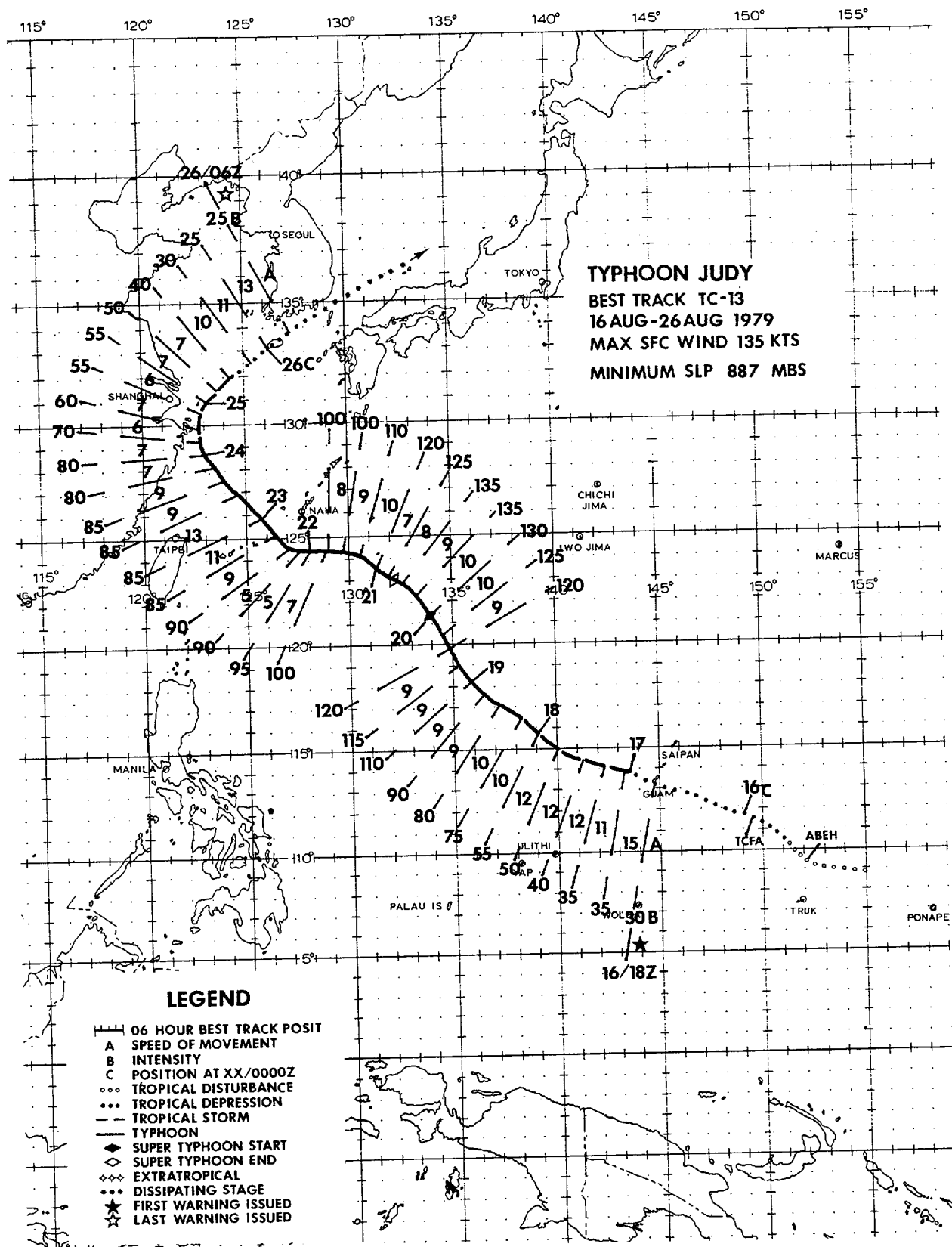
The relationship between Irving's surface and 500 mb centers during the earlier stages of development produced unusually large surface wind radii. Synoptic and aircraft data between 092000Z and 120000Z indicate that Irving's maximum wind band actually existed 150-200 nm (278-370 km) west of the large, calm-wind surface center. Although the maximum wind bands did eventually migrate towards the surface center, the wind radii remained large for the duration of Irving. The large wind radii may be related to Irving's developmental interaction with the 500 mb monsoon low and its large areal extent. Irving never became a tight, well-developed tropical cyclone. Aircraft reconnaissance during the period of eyewall development indicated that Irving had a large 30 nm (56 km) diameter eye with the radius of over 30 kt (15 m/sec) winds extending outward 400 nm (741 km) in the eastern semi-circle.

Unlike Super Typhoon Hope, Typhoon Irving (Fig. 3-12-4) did not follow the intensification pattern suggested by JTWC's Equivalent Potential Temperature ( $\theta_e$ )/Minimum Sea-level Pressure Study. This study indicates that sea-level pressure should fall about 44 mb and maximum surface winds should intensify an average of 55 kt from the point where the  $\theta_e$  and pressure curves intersect (see Super Typhoon Hope, Figure 3-09-2). The reason why Irving failed to intensify further is not known.

Typhoon Irving was the first tropical cyclone to strike Korea in 1979. Rapidly weakening as he made landfall, Irving spared southern Korea from the destructive typhoon force winds he had maintained through most of the East China Sea. Korea did, however, receive torrential rains which produced widespread flooding. The hardest hit area was the island of Cheju Do where 4.3 inches (109.7mm) of rain were reported at Cheju. Official estimates reported 150 dead or missing, 1000-2000 homeless and approximately 10-20 million US dollars damage to food and agriculture.



FIGURE 3-12-4. Although Typhoon Irving did not develop according to intensification studies, Irving did possess good feederband activity and cirrus outflow, 14 August 1979, 0228Z. (DMSP imagery)



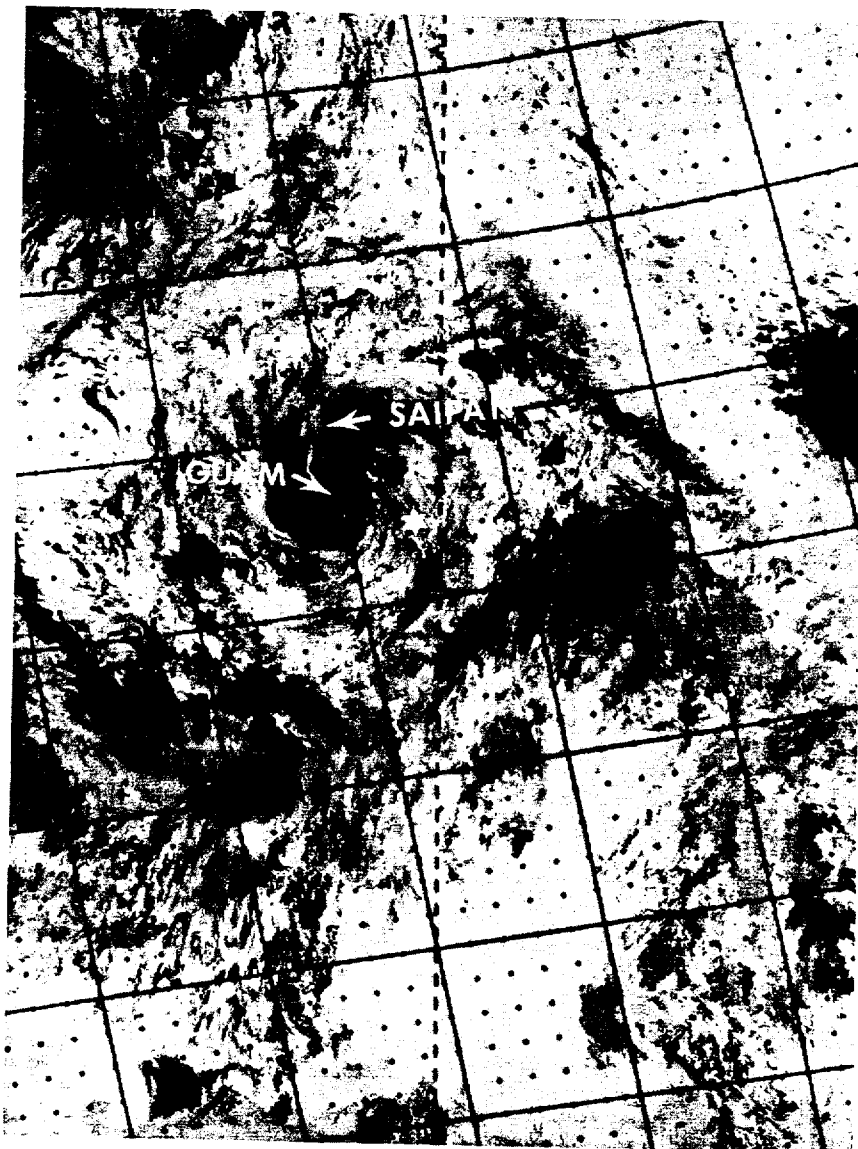


FIGURE 3-13-1. Infrared imagery of tropical disturbance (Judy) while southeast of Guam, 16 August 1979, 1120Z. The star denotes the approximate location of a weak surface center discovered by a reconnaissance aircraft about 4 hours earlier. (DMSP imagery)

Of all the typhoons of 1979, Judy's significance was only surpassed by Super Typhoon Tip. Judy eventually developed into the year's second super typhoon, but more importantly, she served as a reminder of how rapidly a minor tropical disturbance can develop into a dangerous tropical cyclone.

Surface synoptic data from the beginning to the middle of August showed that the area south and east of Guam was fairly inactive. Good cross-equatorial flow was

present, but only a few flare-ups of convective activity were noted. Surface circulations were broad, ill-defined and transient. By 15 August, however, synoptic and satellite data revealed a tropical disturbance, about 120 nm (222 km) east-northeast of Truk, which was to eventually become Typhoon Judy.

This area was closely monitored by JTWC, and when the satellite signature began to improve, a Tropical Cyclone Formation Alert was issued at 152100Z.



No significant pressure falls were observed over the area as the disturbance drifted slowly west-northwestward. A reconnaissance aircraft at 160700Z was able to define only a weak surface circulation with a MSLP of approximately 1006 mb and observed surface winds in the south semi-circle of 10 kt (5 m/sec) or less (Fig. 3-13-1).

Rapid intensification was not expected at that time, but at 161635Z, less than 10 hours after the aircraft investigation, weather radar at Andersen Air Force Base, Guam, located a well-defined circulation center moving west-northwest toward Guam at 15 kt (28 km/hr). Gradient-level wind reports from Guam, Truk, Palau and Ulithi at 161200Z also showed that the low-level inflow pattern associated with the disturbance had increased in areal extent. The disturbance continued tracking toward Guam and at 161800Z the center passed over the Naval Oceanography Command Center (NAVOCEANCOMCEN), Guam building on Nimitz Hill (Fig. 3-13-2). NAVOCEANCOMCEN reported a MSLP of 1001.0 mb and a wind gust to 51 kt (26 m/sec) at that time. Based on this "first-hand" information, JTWC issued the first warning on Tropical Storm Judy at 161900Z. Post-analysis revealed, however, that Judy did not reach tropical storm strength until 170000Z.

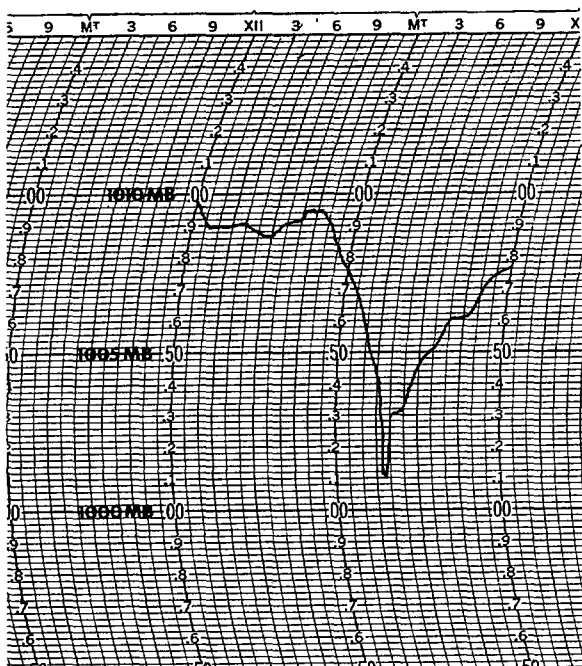


FIGURE 3-13-2. Microbarograph trace recorded at NAVOCEANCOMCEN, Guam during the passage of TD 13 (Judy) at about 161800Z, August 1979.

Judy intensified steadily while following a nearly climatological west-northwest track at 10-12 kt (19-22 km/hr) for the next 24 hours. She reached typhoon strength at approximately 180300Z. After that, a long-wave trough in the mid-level westerlies, moving over Japan toward the Pacific, fractured the subtropical mid-tropospheric ridge north of Judy, allowing her to track more to the northwest.

During the next 36-hour period, after reaching typhoon strength, Judy's central pressure dropped 69 mb and she attained super typhoon strength at 200000Z. Her lowest central pressure, 887 mb, was measured by a reconnaissance aircraft at 192145Z. Three distinct, concentric wall clouds were also noted at that time (Fig. 3-13-3). Super typhoon intensity was maintained until 201500Z, with gradual weakening thereafter.

Forecast aids indicated that Judy would pass to the south of Okinawa, but based on her persistence track and the deep trough that existed over Japan at 500 mb, Judy was forecast to recurve east of Okinawa. The steering aids were reacting to the mid-level PE Forecast series which built the ridge back between Japan and Judy. The numerical forecasts had not been verifying well up to that point, and, thus, the well-entrenched trough was forecast to persist. The numerical forecasts proved to be correct, however, and Judy did pass south of Okinawa before beginning to recurve into the East China Sea.

The rapidly intensifying ridge was expected to drive Judy into the Asian mainland south of Shanghai. The 500 mb analysis at 241200Z provided the first indication that Judy was not going to make landfall. At that time, she was just off the Chinese coast, but north of the mid-level ridge axis. Three-hourly synoptic reports from Sheng-Szu were watched closely and when the winds backed from east at 40 kt (21 m/sec) to north at 35 kt (18 m/sec), there was little doubt that Judy had, in fact, recurved to the northeast.

As Judy recurved, she was downgraded to tropical storm strength based on land synoptic data. Transition to an extratropical system occurred at 261200Z while Judy passed through the Korea Strait.

Due to being still relatively weak while passing over Guam, damage there was insignificant. Damage to Okinawa was also minimal, even though sustained winds of 40 kt (21 m/sec) were experienced for a 28-hour period. Southern Korea did not fare as well, however. One hundred eleven people were killed, over 8,000 houses were inundated, 57 vessels were destroyed and many thousands of acres of crops were ruined by Judy's torrential rains and strong winds.

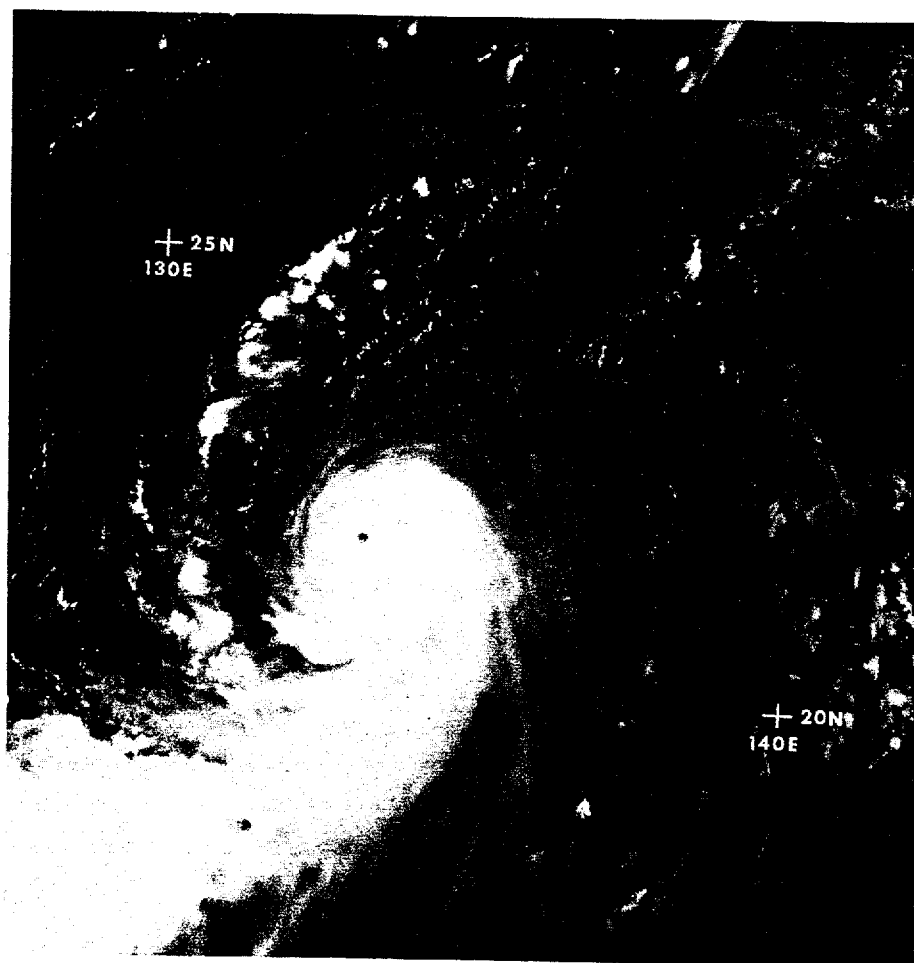
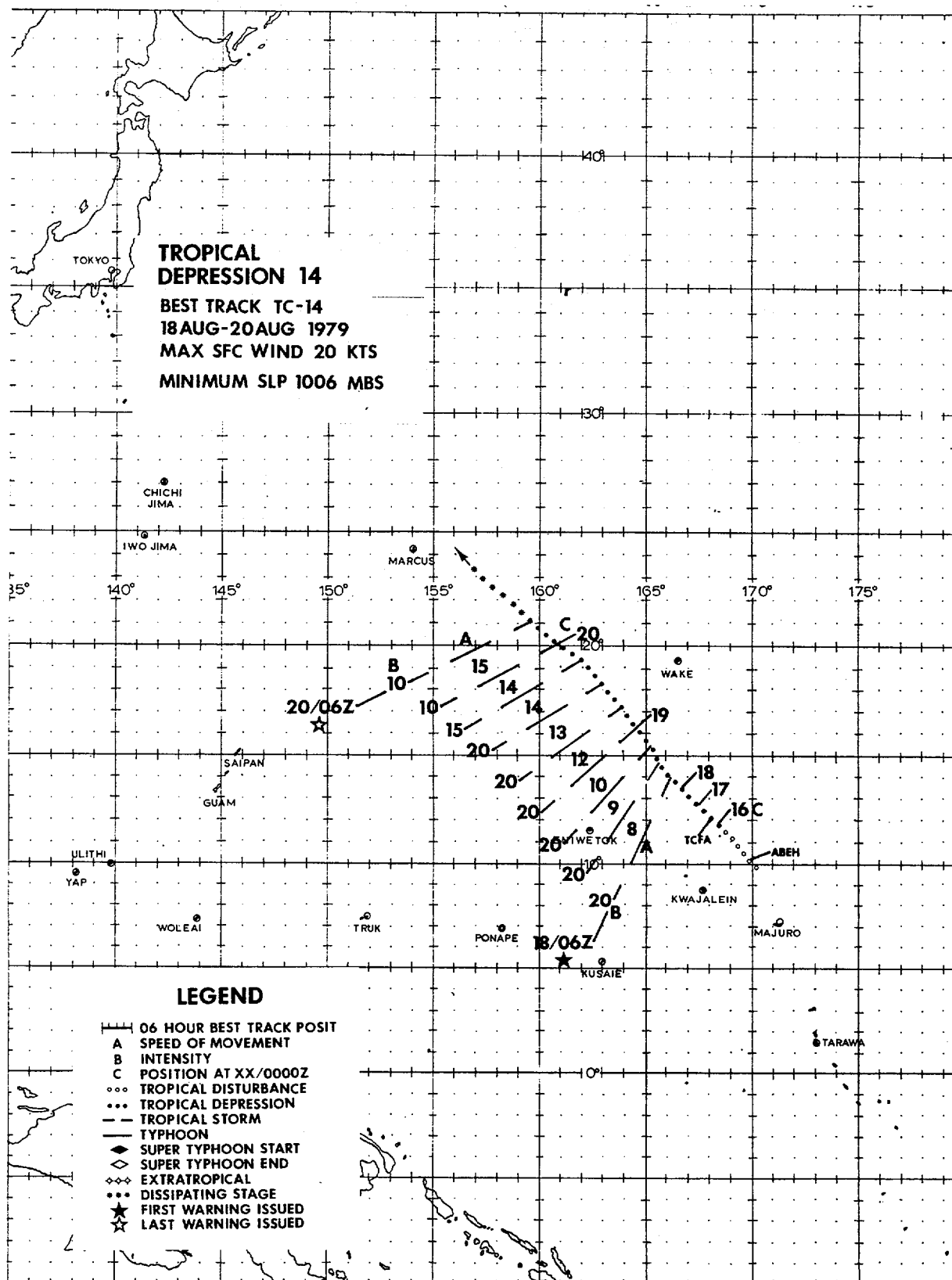
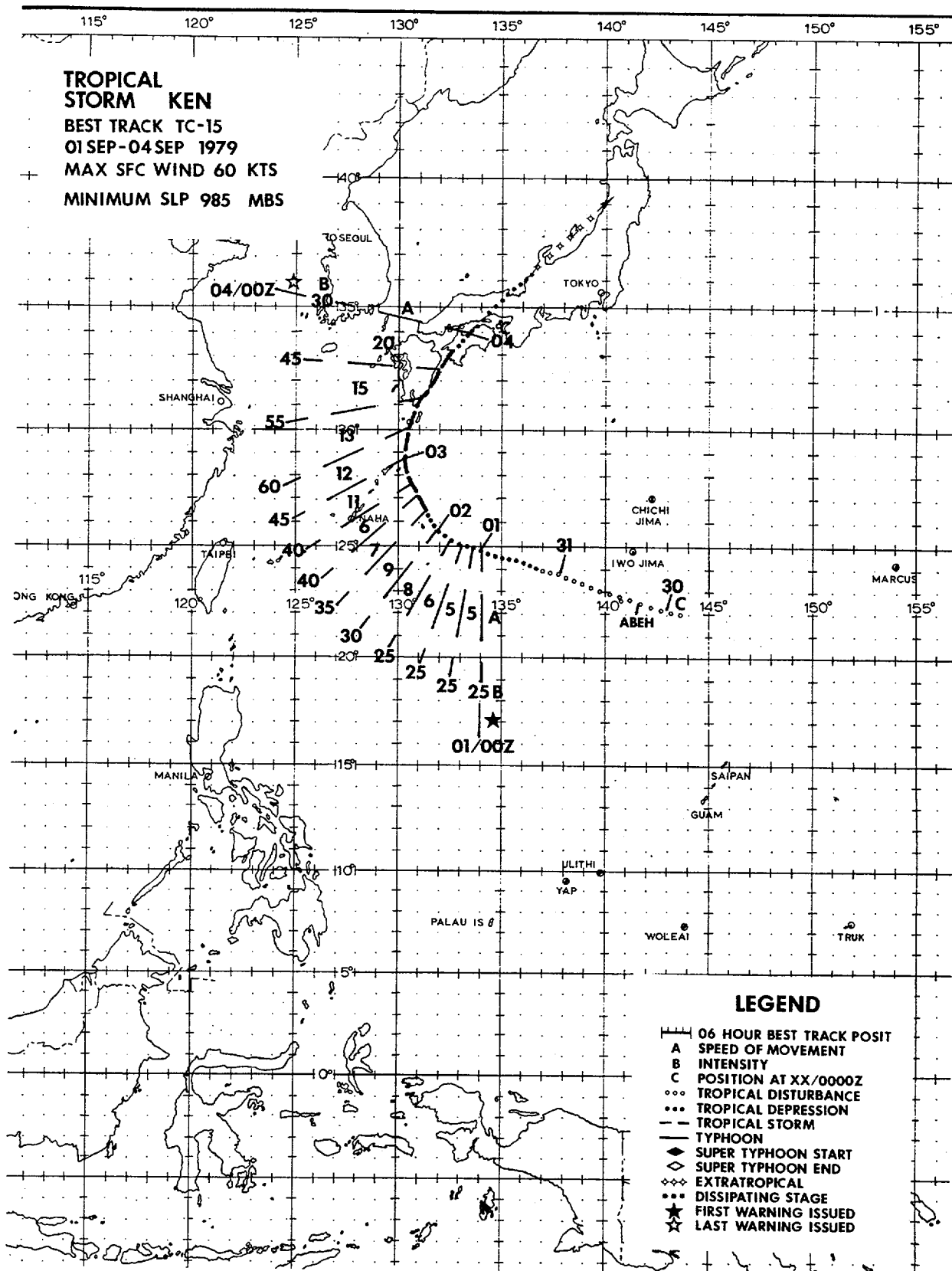
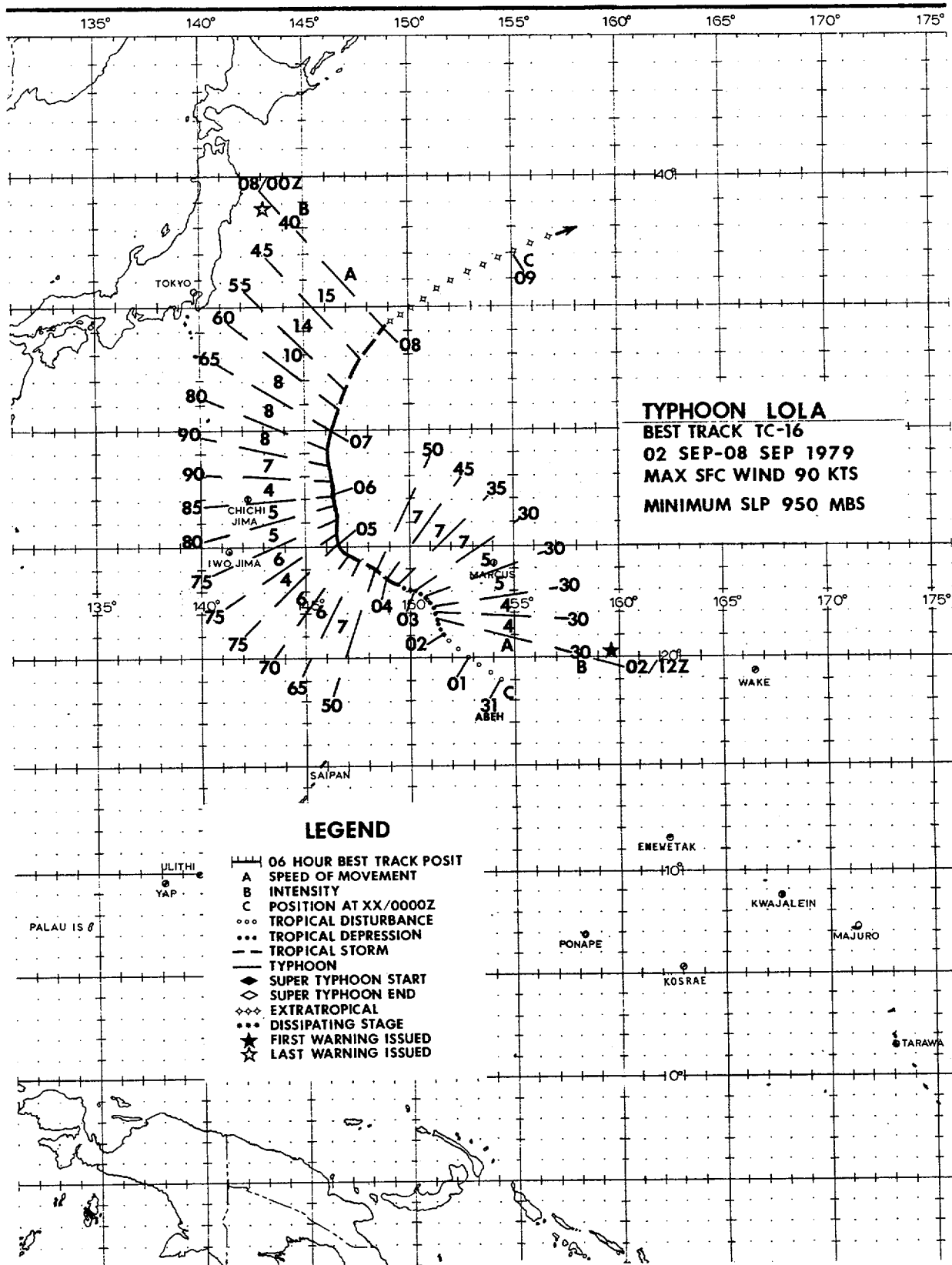


FIGURE 3-13-3. Judy as a super typhoon, 20 August 1979, 0219Z. (DMSP imagery)







TROPICAL STORM KEN (15)  
AND TYPHOON LOLA (16)

Ken and Lola developed almost concurrently along the periphery of an upper-level TUTT. Satellite imagery on 1 September 1979 (Fig. 3-16-1) shows a number of disturbances organized into a line of convection ringing the TUTT in question from north of Kadena to south of Marcus. Ken developed from the disturbance just east of Kadena. At this same time, the disturbance which developed into Lola is south of Marcus and appears quite weak. The largest and most menacing middle disturbance northwest of Guam (Fig. 3-16-1) did not develop.

During the next 48 hours, the TUTT

deepened southwestward over the middle disturbance and suppressed its convection. At the same time, it divided the convective line into the two distinct systems, Ken and Lola (Fig. 3-16-2).

After forming, Ken and Lola began to move in similar recurvature tracks. Ken tracked northward into the Sea of Japan reaching a maximum intensity of 60 kt (31 m/sec). Lola intensified into a typhoon and eventually transitioned into an extra-tropical system over the cooler waters east of Japan.

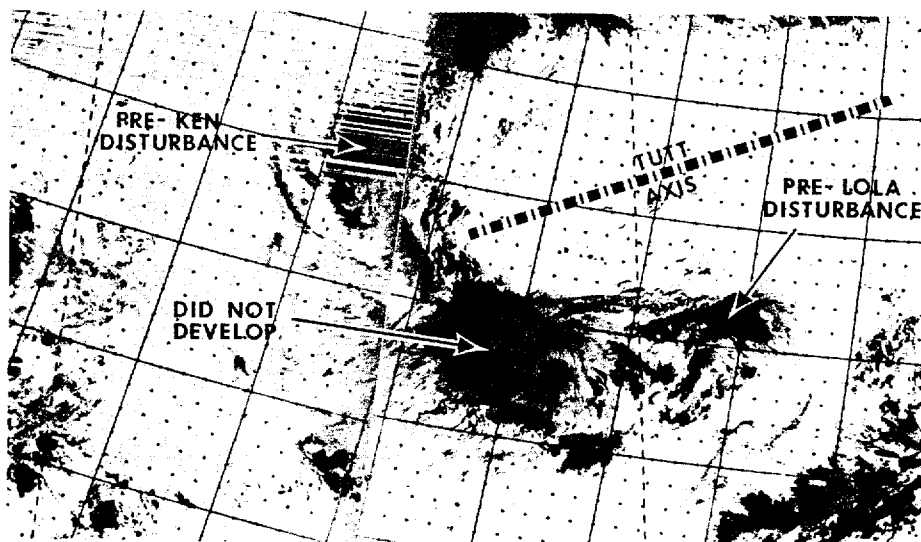


FIGURE 3-16-1. Line of tropical disturbances from which TS Ken and TY Lola eventually developed, 312257Z Aug - 010039Z Sep 1979. (DMSP imagery)

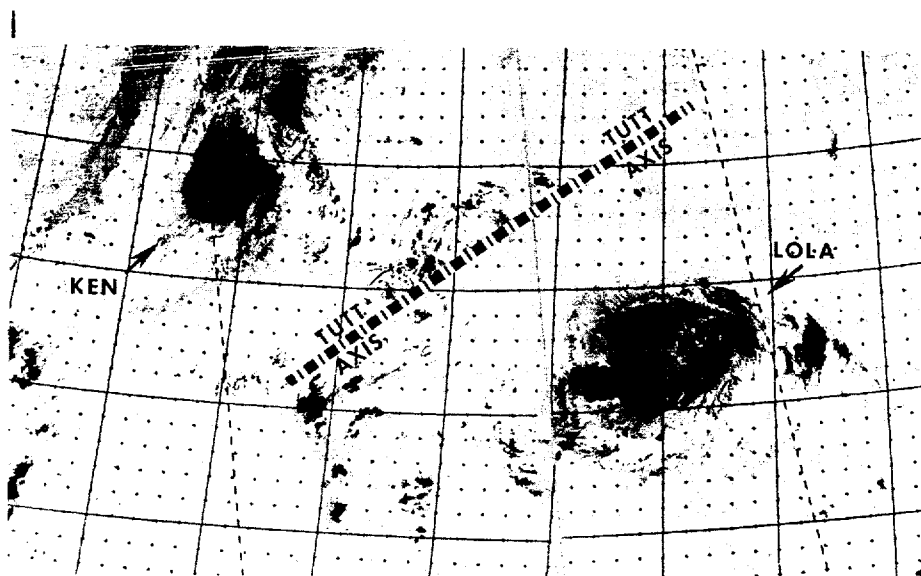
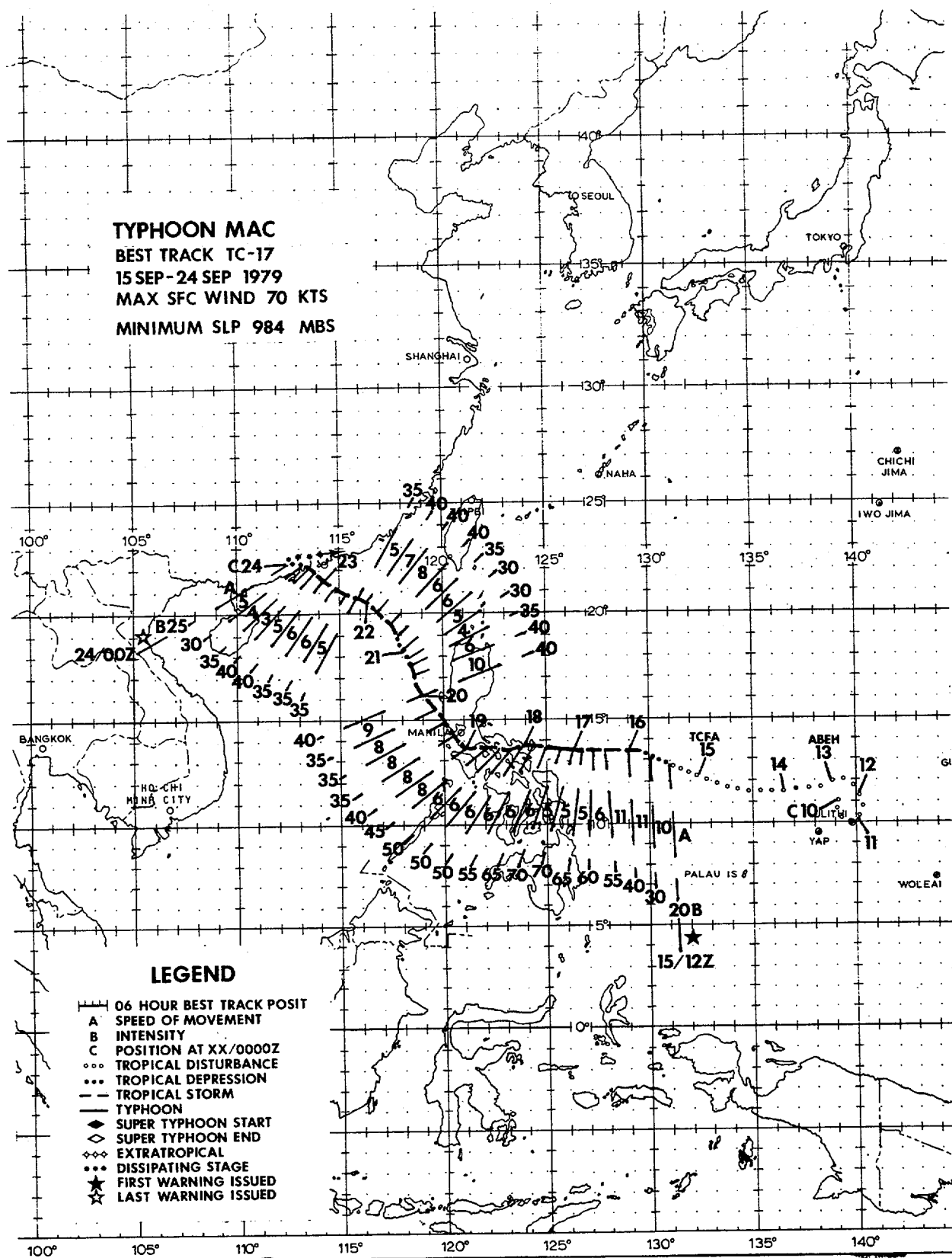


FIGURE 3-16-2. Ken at 45 kt (23 m/sec) intensity and Lola at 36 kt (15 m/sec) intensity, 022221Z - 030003Z Sep 1979. (DMSP imagery)



TYPHOON MAC (17) AND  
TROPICAL STORM NANCY (18)

Typhoon Mac developed from a weak surface circulation northeast of Yap in September 1979. This circulation tracked westward, reaching tropical storm intensity by 160000Z. Mac followed the climatological intensification rate for tropical cyclones approaching the Philippines and reached typhoon intensity prior to making landfall. Frictional effects caused Mac to weaken slowly as he tracked across southern Luzon towards the South China Sea. The unexpected development of Tropical Storm Nancy east of Hai-nan Island influenced Mac's track in the South China Sea.

JTWC's real-time forecasts do not always reflect the actual intensity of a tropical cyclone. Rapid intensification or weakening, peripheral data unavailable due to geographical restrictions, and tight maximum wind bands, which are not initially detected, all reduce the accuracy of intensity estimates provided in tropical cyclone warnings. These intensity discrepancies often go unrecognized until discovered during post-analysis, as in the case of Typhoon Mac.

Reanalysis of aircraft reconnaissance data from 16-18 September indicates that Mac most probably intensified to typhoon intensity by 161800Z. During the period 16-18 September, aircraft reconnaissance at 160503Z reported 68 kt (35 m/sec) at 1500 ft (457 m) and 60 kt (31 m/sec) on the surface prior to encountering moderate turbulence which forced the aircraft to climb through the overcast stratocumulus cloud layer above. Subsequent reconnaissance data at 170810Z confirmed typhoon intensity by locating 80-90 kt (41-46 m/sec) surface winds in a 10-nm (19 km) wide band tucked under the strong eastern feederband. Mac made landfall prior to the next scheduled aircraft fix with geographical constraints severely reducing peripheral data collection.

Although real-time data were available which indicated Mac had possibly reached typhoon intensity, the isolated reports of strong winds were dismissed as gusts associated with lower velocity sustained winds. (Aircraft data are occasionally not used verbatim when they fall outside reasonable limits after being analyzed with available surface reports, satellite data intensity estimates and the JTWC Maximum-Wind Minimum-Pressure Relationship (Atkinson and Holliday, 1977).) During post-analysis, the reconnaissance data were re-examined using an intensity study of tropical cyclones crossing the Philippines (Sikora, 1976). For typhoons with maximum sustained winds of less than 80 kt (41 m/sec), the study shows that an average intensification of 30 kt (15 m/sec) can be expected for tropical cyclones which follow a track similar to Mac's. Reanalysis of the period between 151800Z and 180000Z shows, in fact, that Mac intensified to typhoon intensity before weakening from frictional effects over Catanduanes Island on 18 September (Fig. 3-17-1).

The unexpected development of a second tropical cyclone in the South China Sea (SCS) produced a series of track and intensity modifications in Typhoon Mac. Upon exiting the Philippines, Mac, which was originally forecast to track west-northwest into the SCS, began a Fujiwhara interaction (Fig. 3-18-2) with the rapidly developing Tropical Storm Nancy located near Hai-nan Island. Instead of tracking west-northwest, Mac tracked north-northwest, skirting Cubi Point Naval Air Station, Philippines, on his new track toward Hong Kong. Strong anticyclonic outflow from Nancy sheared Mac's convection towards the southwest with aircraft reconnaissance reporting an exposed low-level circulation of 30-35 kt (15-18 m/sec) intensity on the 20th.

Weak steering currents allowed Nancy to take a cyclonic track across southern Hai-nan Island before heading southwestward into Vietnam. Nancy's southwestward track towards landfall forced Mac further north than originally forecast. Mac eventually passed just south of Hong Kong. Ironically, Nancy's development, which caused Mac to track towards Hong Kong, also helped to spare Hong Kong from potential typhoon force winds. Nancy's upper-level outflow, which dominated the SCS from 19-23 September, produced strong vertical shear over Mac and slowed his rate of reintensification. Typhoon Mac only reached minimal tropical storm intensity prior to making landfall west of Hong Kong.

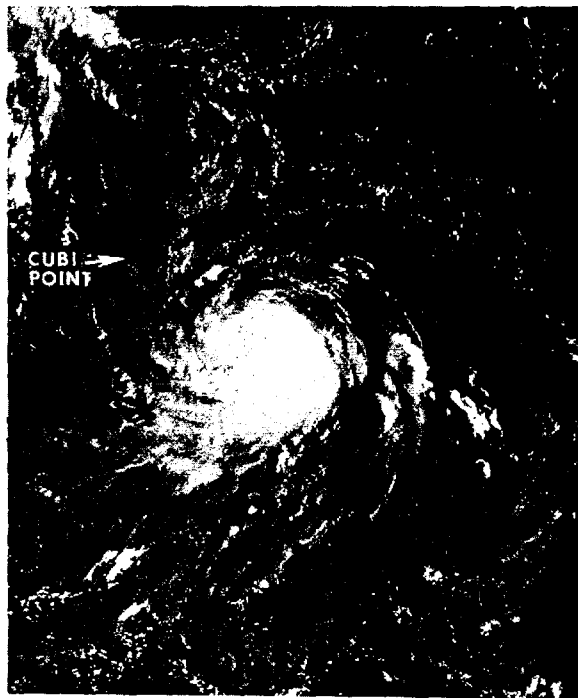
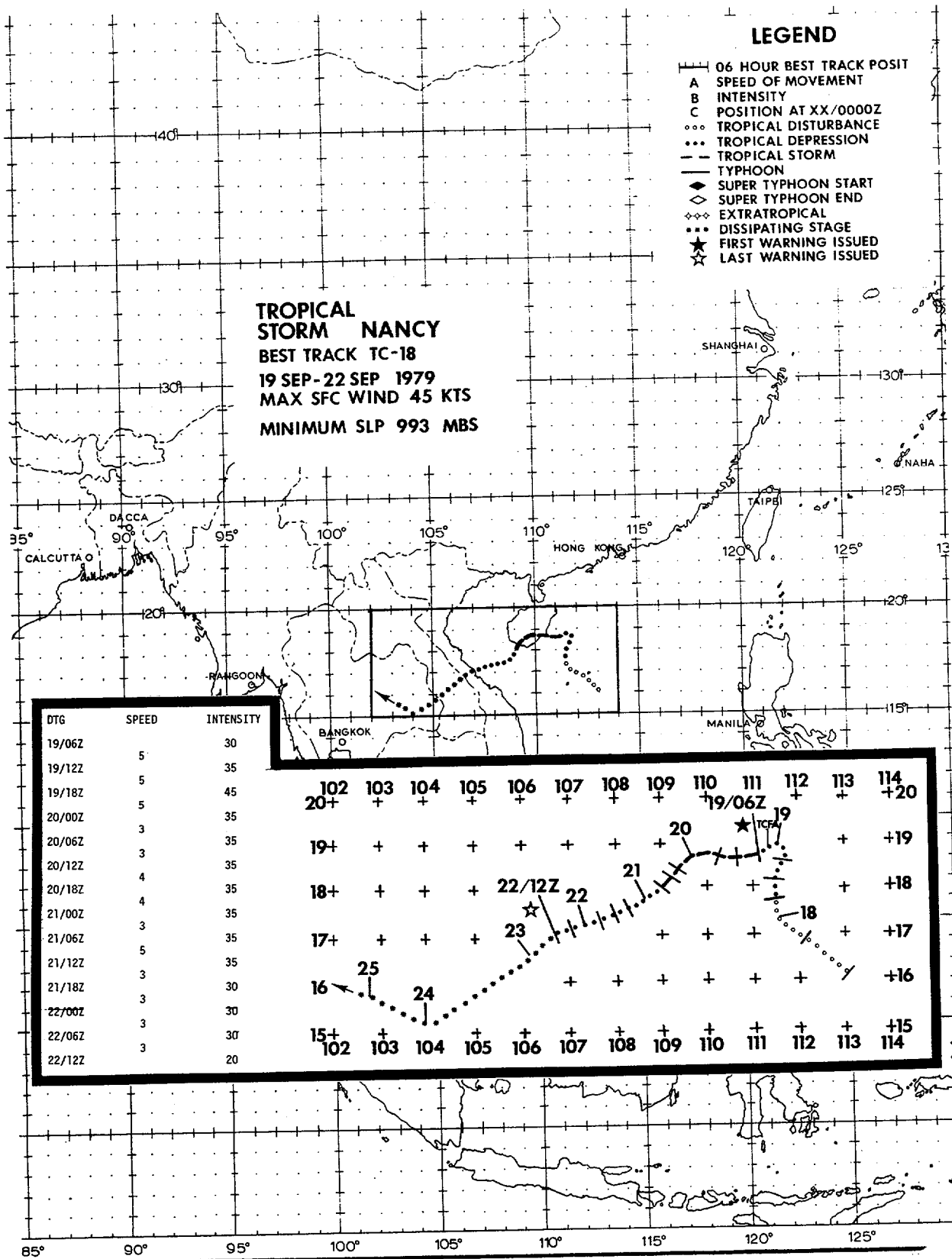


FIGURE 3-17-1. Typhoon Mac after crossing Catanduanes Island, Philippines, 18 September 1979, 0038Z. (DMSP imagery)





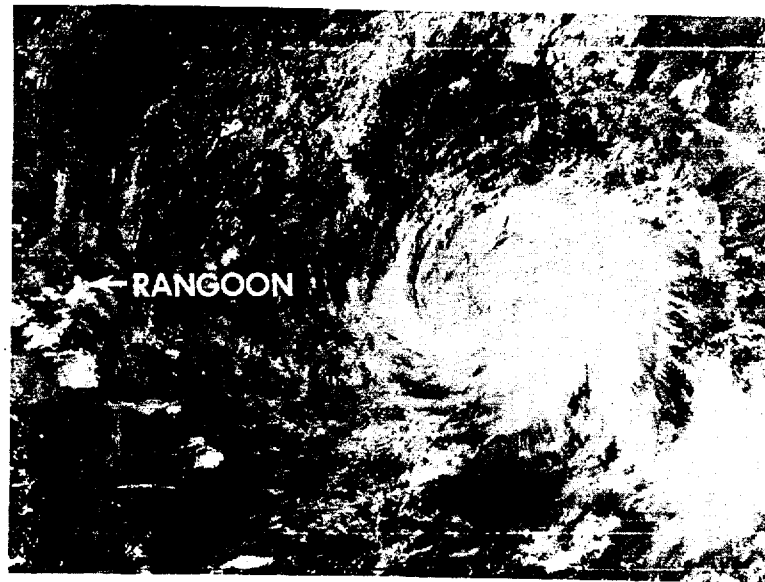


FIGURE 3-18-1. Tropical Storm Nancy at 35 kt (18 m/sec) intensity just after landfall on the southern end of Hai-nan Island, 20 September 1979, 0143Z. (DMSP imagery from Det 8, 1WW, Kadena AB, Okinawa)

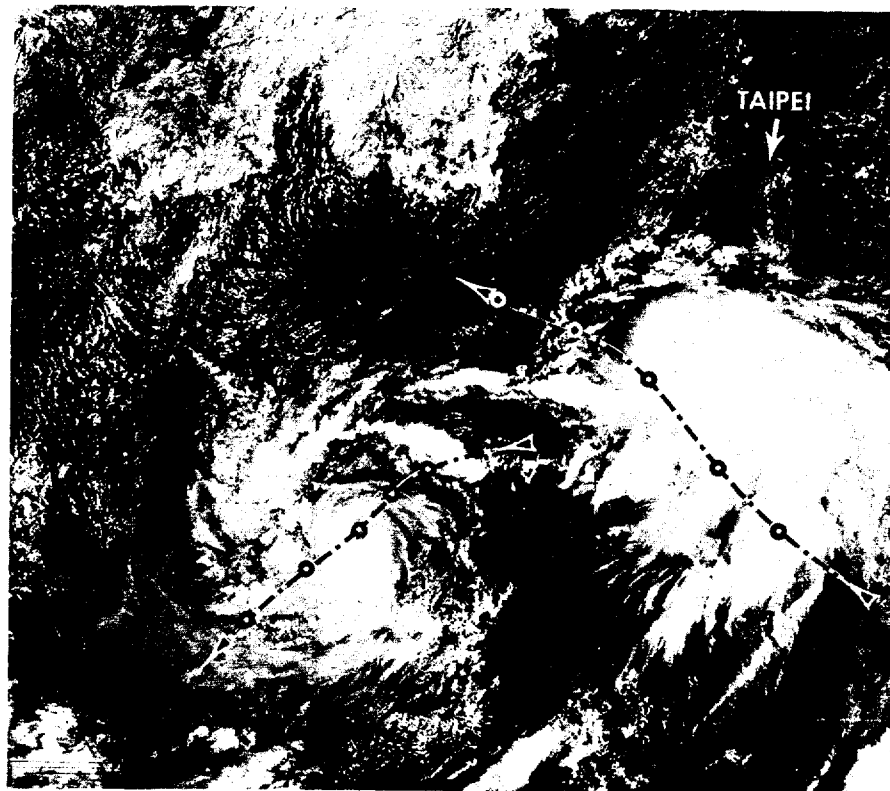
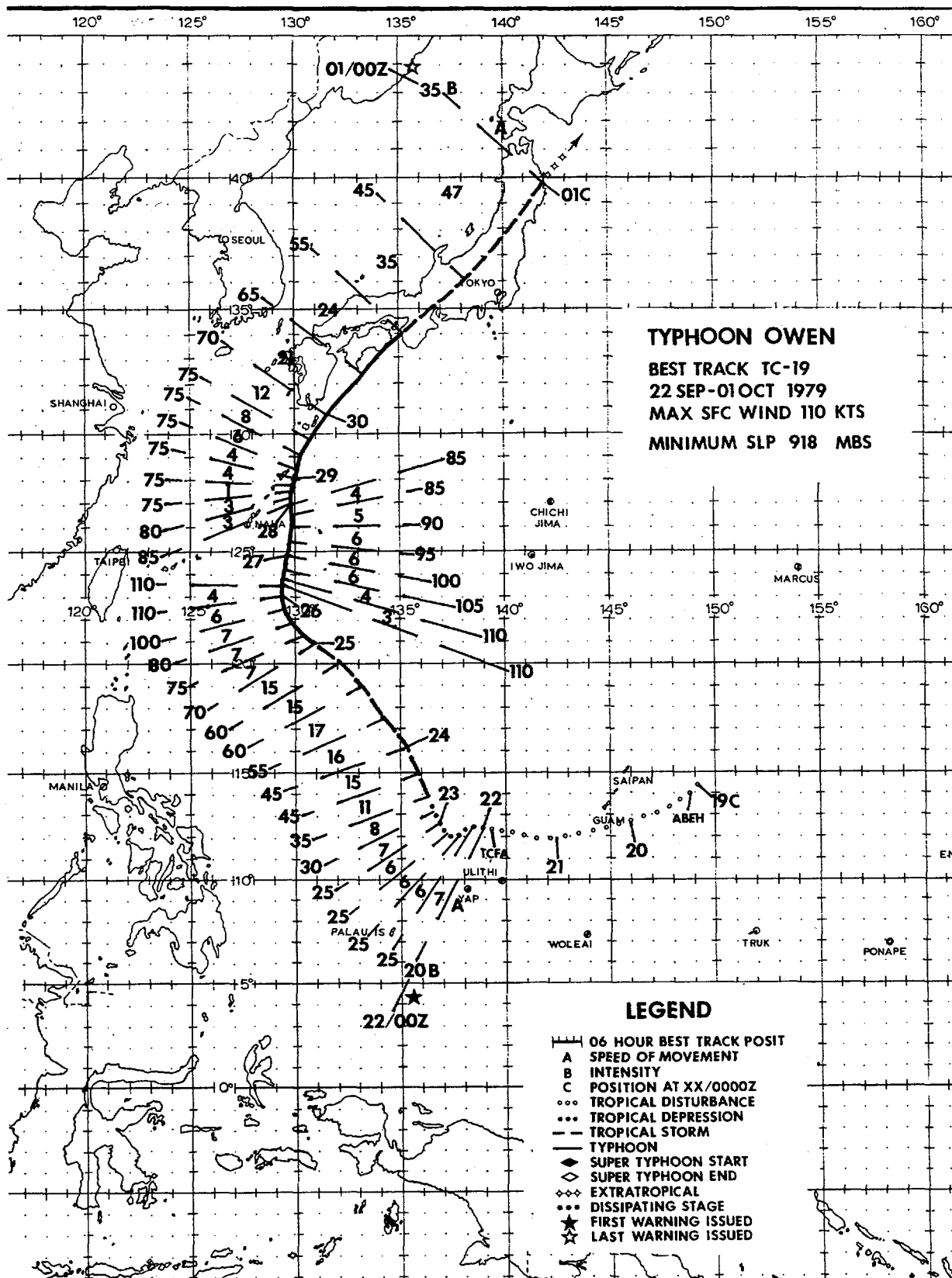


FIGURE 3-18-2. Typhoon Mac and Tropical Storm Nancy undergoing Fujiwhara interaction over the South China Sea, 22 September 1979, 0302Z. The 48-hour tracks before and after picture time are superimposed (Dots bracket 24-hour intervals). (DMSP imagery from Det 5, 1WW, Clark AB, RP)



Typhoon Owen developed from a disturbance which tracked south of Guam during 20 September 1979. Two days later, satellite imagery (Fig. 3-19-1) showed that the system was organizing at the same time that aircraft reconnaissance data indicated a definite surface circulation with a 1000 mb central pressure. This prompted JTWC to issue a tropical depression warning on the system at 220000Z.

During the 2 days prior to and 1 day after 22 September, the system moved on a generally westward track at 5 to 8 kt (9 to 15 km/hr). This speed and direction was in good agreement with climatological tracks. Also, the 500 mb analysis showed a strong subtropical ridge which indicated westward steering. Based on this information, JTWC forecast westward movement for the first 8 warnings. However, Owen unexpectedly turned sharply to the north and began moving at speeds of 15 kt (28 km/hr).

Post-analysis revealed a possible reason for this movement. Figure 3-19-2 shows

the 221200Z analyses at 500 mb and 200 mb superimposed. An upper-level trough is evident on the 200 mb analysis just west of the cyclone. Southerly winds of 50 kt (26 m/sec) were observed on the eastern periphery of the trough. Considerable vertical shear existed in the layer from 500 mb to 200 mb. It appears that the steering and depth of this upper-level trough rather than 500 mb steering was the dominant feature in Owen's movement. Under its influence, Owen tracked generally northward throughout his lifetime, although undergoing major changes in speed. He slowed to a barely perceptible 1-kt (2 km/hr) movement just northeast of Okinawa (at the latitude of the subtropical ridge axis) and then dramatically accelerated to 24 kt (44 km/hr) 36 hours later under vertically consistent westerly steering. At this time, Owen made landfall near Osaka, Japan and began weakening in intensity while still accelerating to 47 kt (87 km/hr). Eventually, he transitioned into an extratropical system but not before reaching a maximum intensity of 110 kt (57 m/sec) (Fig. 3-19-3) on 26 September.

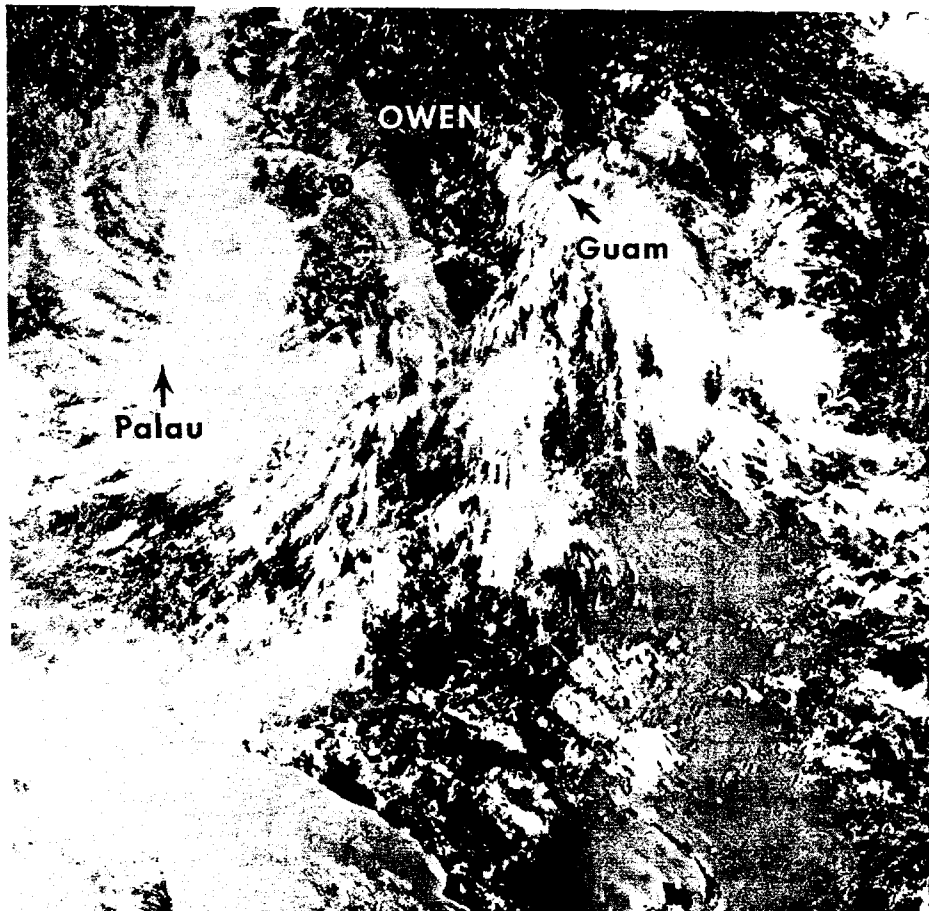


FIGURE 3-19-1. Typhoon Owen as a tropical disturbance, 21 September 1979, 2326Z. (DMSP imagery)

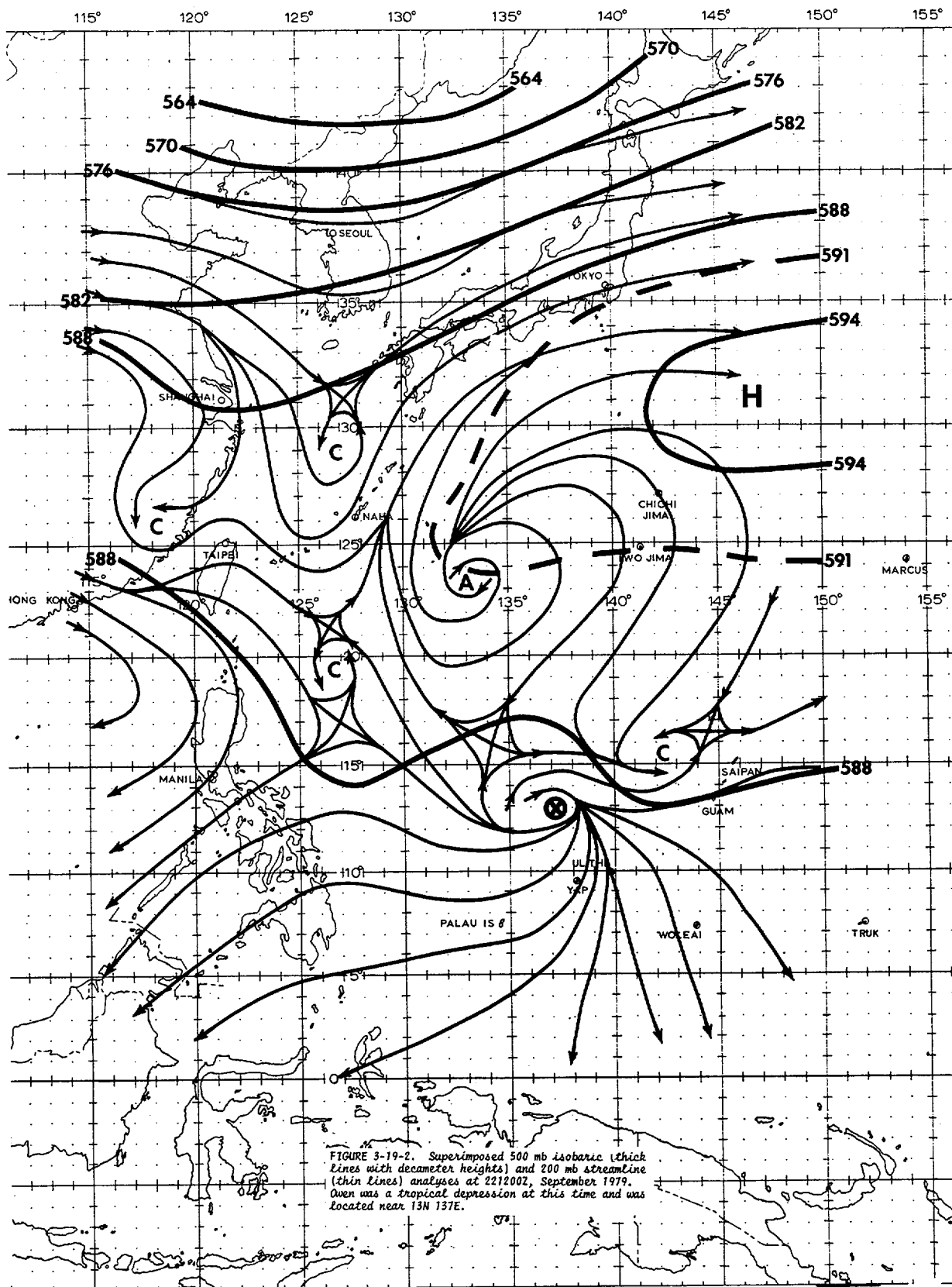
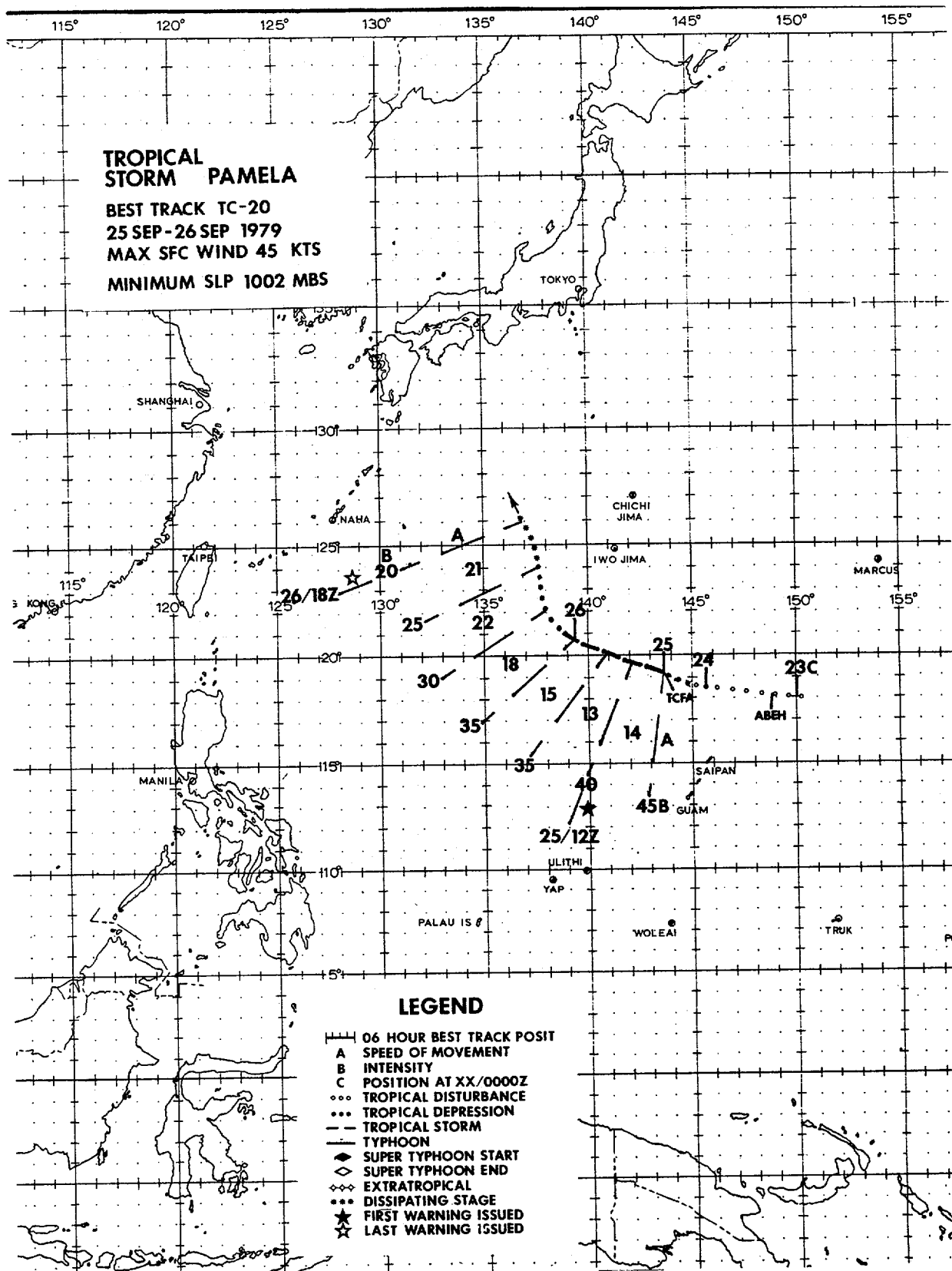




FIGURE 3-19-3. Typhoon Owen at maximum intensity of 110 kt (57 m/sec), 26 September 1979, 0145Z. (DMSP imagery)



Developing at the apex of a wave in the easterly flow in late September 1979, Tropical Storm Pamela tracked westward, north of the Mariana Islands, and dissipated in Typhoon Owen's eastern feeder band under strong vertical shear (Fig. 3-20-1).

A JTWC pressure-wind relationship study (Atkinson and Holliday, 1977) suggested TS Pamela's maximum intensity should have ranged between 25-30 kt (13-15 m/sec) for the concomitant 1002-1003 mb minimum sea-level pressure reported. Instead, aircraft data at 250827Z reported a very narrow,

transient wind band of 60 kt (31 m/sec) north and east of the surface center. The ARWO on this mission indicated that surface winds may have been even higher than the reported 60 kt (31 m/sec). Subsequent aircraft investigations were not able to locate winds greater than 25 kt (13 m/sec). The occurrence of maximum winds which exceed the range of the JTWC tropical cyclone pressure-wind relationship is encountered several times each season. Although several explanations have been offered for these anomalies, none have been substantiated.

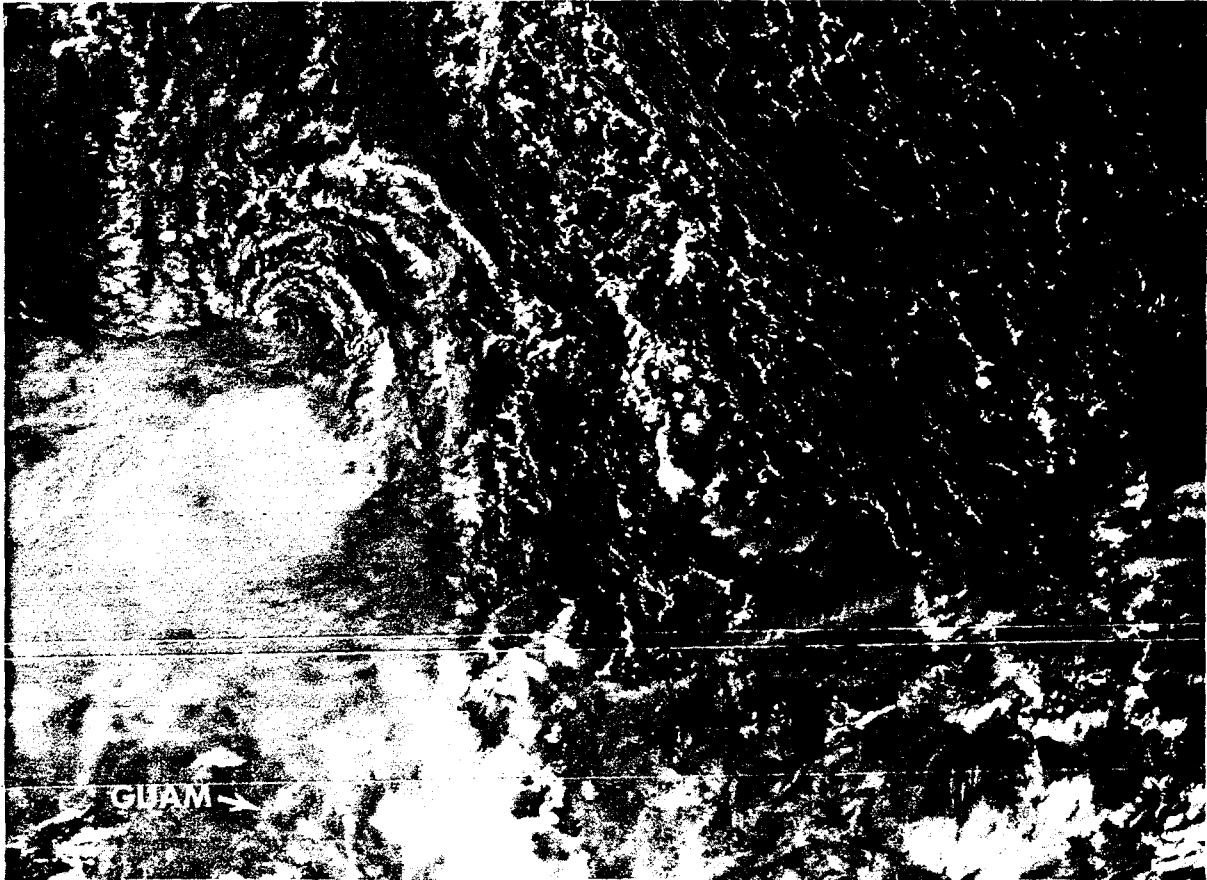
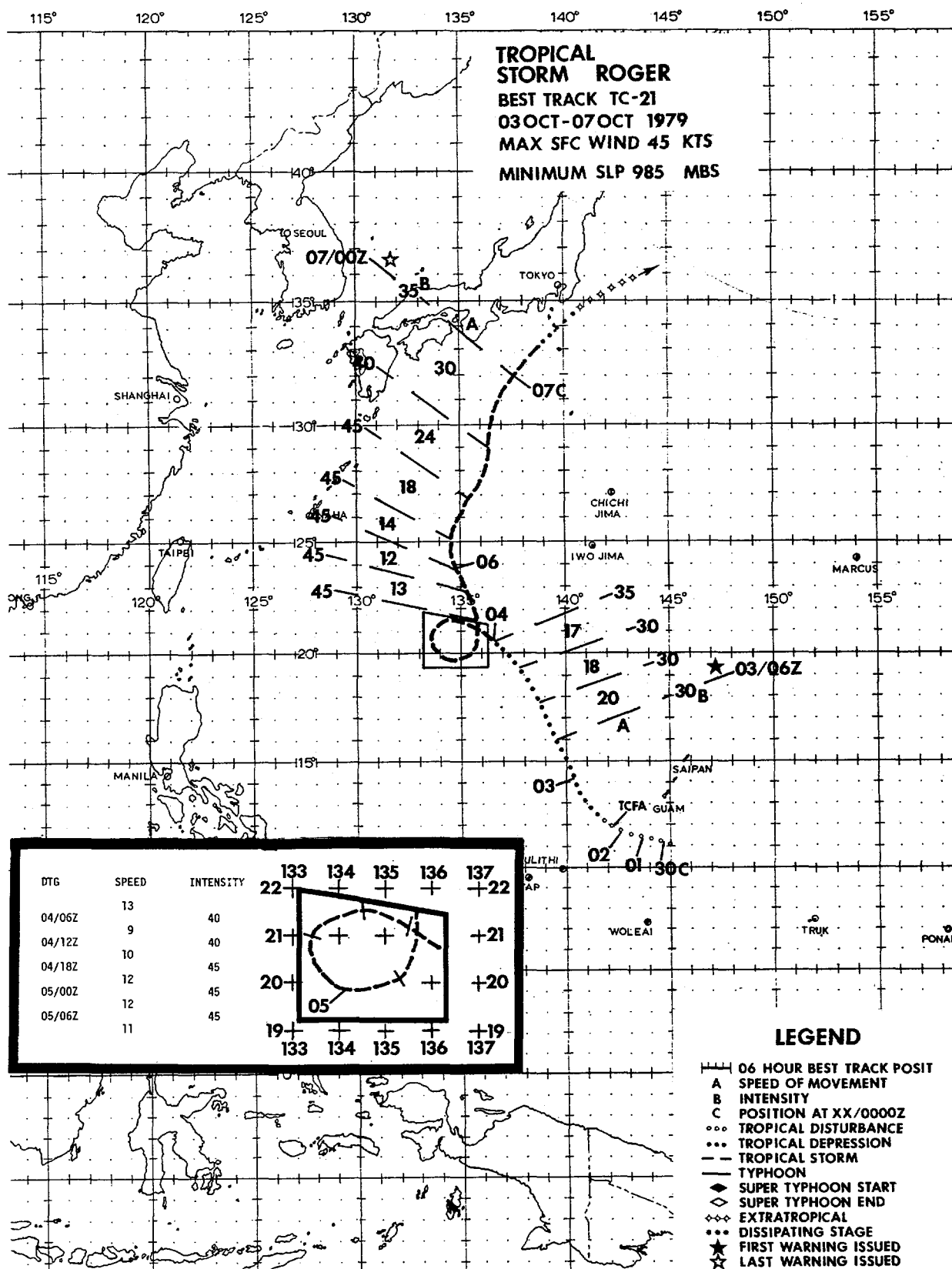


FIGURE 3-20-1. Tropical Storm Pamela with maximum sustained winds of 45 kt (23 m/sec), 24 September 1979, 2232Z. The exposed low-level circulation was a result of strong vertical shear produced by Typhoon Owen. (DMSP imagery)





As Typhoon Owen began recurving toward Japan, activity increased in the monsoon trough that extended over the Caroline Islands. The increased activity was noted in the Significant Tropical Weather Advisory (ABEH PGTW) on 28 September. For the next 5 days, 2 weak surface circulations and associated cloud clusters within the broad trough, one southwest of Guam and the other southeast of Guam, were closely monitored. As Owen began weakening over Japan, the southwest monsoon flow into the trough oriented NW-SE increased on 30 September, and a line of strong convective activity developed from the southern Philippines to a position south of Guam.

Post-analysis indicated the existence of a weak circulation southwest of Guam which was to become Tropical Storm Roger. During the entire time preceding the issuance of the first warning on Roger, JTWC's attention was focused on another area of major convective activity 5° west of the circulation center which was associated with strong low-level convergence and cyclonic shear. Gradient-level winds at Yap of 56 kt (29 m/sec), Palau 52 kt (27 m/sec) and Guam 28 kt (14 m/sec) are indicative of the strong low-level winds around the periphery of the trough. Thus, the initial and the reissued formation alerts (020600Z Oct and 022200Z Oct) covered the area of heavy convective activity rather than the actual surface circulation center.

Numbered warnings began at 0600Z on 3 October when a reconnaissance aircraft at

030220Z reported a surface pressure of 998 mb and estimated surface winds of 40 kt (21 m/sec) in a band of strong southwesterly flow 60 nm (111 km) south of the surface center. The aircraft also observed a calm wind center at the surface of 30 nm (56 km) in diameter with clear skies over the area.

Synoptic and satellite data at 031200Z indicated that TD 21 was beginning to separate from the broad trough as convective activity was becoming more directly associated with the circulation center (Fig. 3-21-1). TD 21 was upgraded to a tropical storm at 0600Z on 4 October based on 35 kt (18 m/sec) surface winds and a 982 mb sea-level pressure reported by aircraft reconnaissance at 040308Z. Post-analysis indicates tropical storm intensity was attained 6 hours earlier.

A break in the mid-tropospheric subtropical ridge north of Roger existed as Owen recurved over Japan. The strong mid-level southeasterly steering current along the southwestern periphery of the ridge was responsible for Roger's 15 to 20 kt (8 to 10 m/sec) northwestward movement. The ridge retreated eastward between 0000Z and 1200Z on 4 October as a mid-level trough deepened over Korea. The loss of definitive steering flow permitted Roger to execute a cyclonic loop. After emerging from the loop, Roger continued on a northwestward track until north of the ridge axis, after which he accelerated north-northeastward. Extratropical transition was complete by 070600Z as Roger merged with a cold front south of Japan.

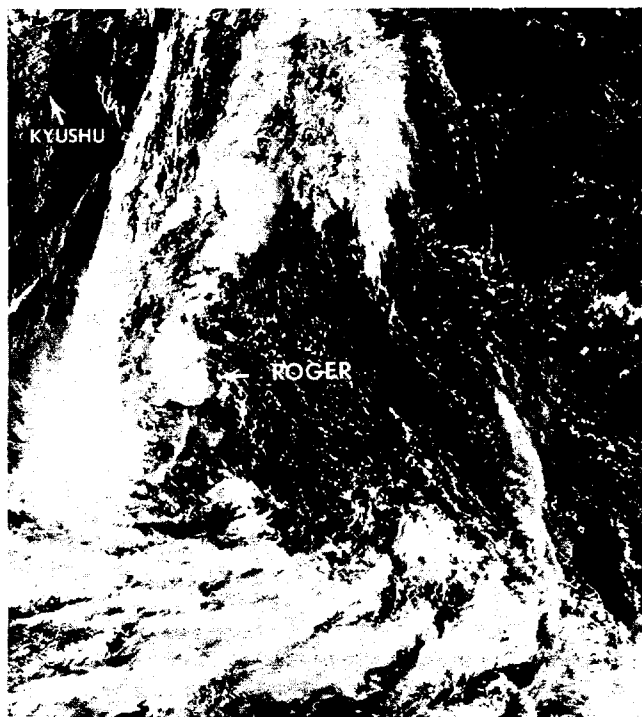
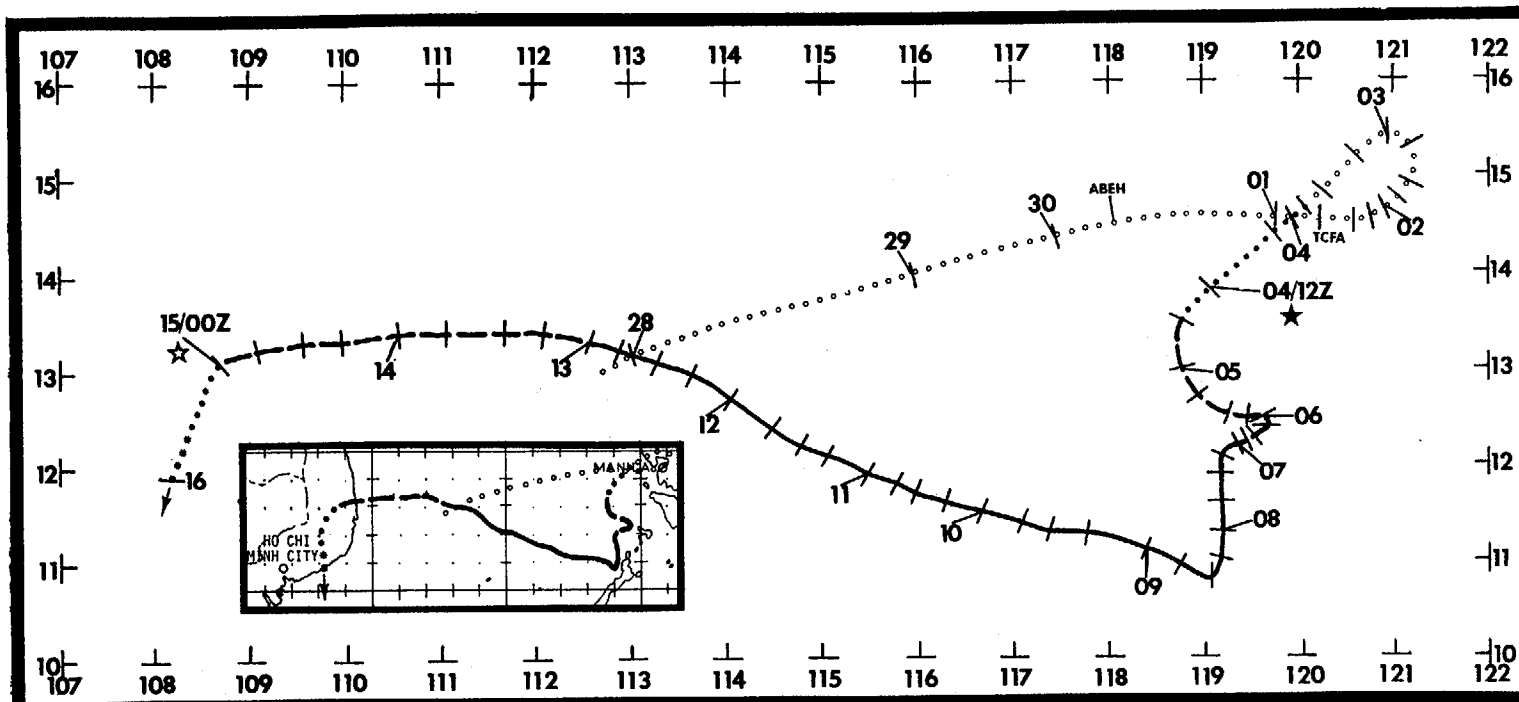


FIGURE 3-21-1. Tropical Storm Roger at 35 kt (18 m/sec) intensity 04 October 1979, 0054Z. (DMSP imagery)



DTG	SPEED	INTENSITY	DTG	SPEED	INTENSITY	DTG	SPEED	INTENSITY	DTG	SPEED	INTENSITY
04/12Z	5	30	07/18Z	3	75	10/18Z	3	100	14/00Z	6	55
04/18Z	5	35	08/00Z	3	75	11/00Z	4	100	14/06Z	5	50
05/00Z	4	40	08/06Z	3	75	11/06Z	3	90	14/12Z	5	50
05/06Z	3	40	08/12Z	2	75	11/12Z	3	85	14/18Z	5	35
05/12Z	2	40	08/18Z	3	75	11/18Z	4	75	15/00Z	5	20
05/18Z	2	40	09/00Z	4	85	12/00Z	5	75			
06/00Z	1	40	09/06Z	6	90	12/06Z	5	70			
06/06Z	1	40	09/12Z	5	90	12/12Z	4	65			
06/12Z	1	45	09/18Z	4	95	12/18Z	4	65			
06/18Z	1	50	10/00Z	4	110	13/00Z	4	60			
07/00Z	2	60	10/06Z	3	110	13/06Z	5	60			
07/06Z	2	75	10/12Z	3	100	13/12Z	6	60			
07/12Z	2	75				13/18Z		60			

**TYPHOON SARAH**  
**BEST TRACK TC-22**  
**04 OCT-15 OCT 1979**  
**MAX SFC WIND 110 KTS**  
**MINIMUM SLP 929 MBS**

#### LEGEND

- 06 HOUR BEST TRACK POSIT
- A SPEED OF MOVEMENT
- B INTENSITY
- C POSITION AT XX/0000Z
- ... TROPICAL DISTURBANCE
- ... TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ DISSIPATING STAGE
- ★ FIRST WARNING ISSUED
- ☆ LAST WARNING ISSUED

Typhoon Sarah spawned in the monsoonal trough during late September 1979. This trough extended from the southwestern portion of the South China Sea toward Luzon. A northeast monsoon surge existed north of the trough, while the southwest monsoon dominated the area south of the trough. The circulation was steered initially by the southwest monsoon and then later by the first northeast surge of the fall from the Asian mainland. During the last few days of September, the circulation meandered slowly toward Luzon under the influence of the southwest monsoon, and then looped over Luzon during the first three days of October as a mid-tropospheric short-wave trough moved eastward north of Luzon. Once the short-wave trough had moved east of the circulation, the northeast surge intensified and became more of an influence as the circulation finished its loop and began its south-southwest track.

On 5 and 6 October, Sarah, now a tropical storm, apparently was again influenced by another mid-tropospheric short-wave trough which moved across Sarah's longitudinal position and induced the brief eastward movement in her track. At this time, the southwest monsoon also increased in intensity and may have been another factor in steering Sarah eastward. For almost the entire period that Sarah was tracking southward, there was a weakness in the mid-tropospheric ridge between the Philippines and the Asian mainland, enabling Sarah's track to be influenced by short-wave troughs. This weakness in the ridge resulted in mid-tropospheric flow that was too weak to significantly affect the steering of Sarah. This weakness allowed the surface winds to dictate Sarah's direction of motion through the first 8 days of October. Figures 3-22-1 and 3-22-2 illustrate the surface and mid-level flow patterns which influenced Sarah during this phase of her track.

During Sarah's depression stage, strong easterlies in the upper-troposphere restricted Sarah's outflow to the northeast, thus inhibiting development into a tropical storm. As Sarah proceeded southward, the easterlies decreased in strength, outflow increased, and Sarah intensified to tropical storm and then typhoon strength. It is very interesting to note that Sarah intensified to typhoon strength while tracking southward which is quite unusual for a tropical cyclone. Several aircraft reconnaissance flights reported that Sarah had attained typhoon strength even though her cloud structure was not well organized.

During the first several days of October when Sarah was slowly developing to typhoon strength and moving south, Palawan Island and the central Philippines were battered by high winds and rain. These areas were inundated by flooding and landslides which caused massive crop damage and death. Many villages were cut off from any

source of food, fresh water, and other necessities for survival. Four deaths were attributed to Sarah. On 8 October, Sarah finally began to track westward and the weather finally cleared over Palawan Island and the central Philippines. Sarah's change in track was due to the strengthening of the mid-tropospheric ridge north of Sarah from Luzon across the South China Sea into Asia. Aircraft reconnaissance early on the 9th reported that Sarah's structure had become better organized. Earlier aircraft reported that Sarah was not vertically aligned; but on the 9th, the mid-level center had become vertically aligned with the surface center. With vertical alignment and improved upper-level outflow, Sarah's intensity increased to 110 kt (57 m/sec) as she became a most impressive storm. This is in contrast to her unusual origin.

After Sarah reached peak intensity early on 10 October, she began to slowly weaken as



FIGURE 3-22-3. Sarah with 60 kt (31 m/sec) intensity one day prior to landfall over Vietnam, 13 October 1979, 0136Z. (DMSP imagery)

she tracked west-northwestward (Fig. 3-22-3). Sarah continued on a west-northwest track until dissipation over Vietnam on 17 October. After 20 days, she dissipated within 300 nm (556 km) of her origin as a monsoon depression on 28 September.

FIGURES 3-22-1 and 3-22-2 are on following pages.

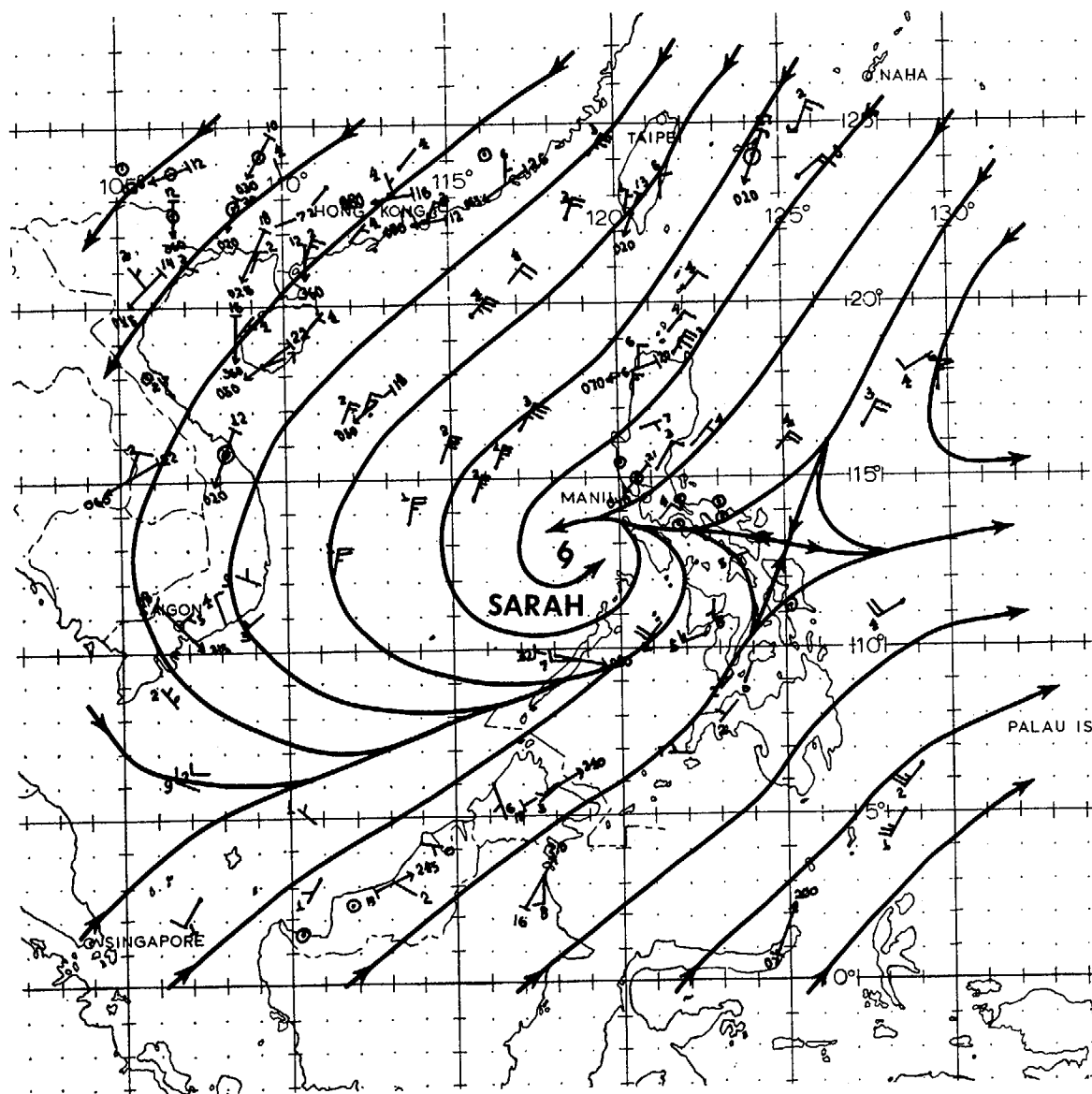


FIGURE 3-22-1. The 050000Z October 1979 surface (—) / gradient-level (ddd —) wind data and streamline analysis. Wind speeds are in knots.

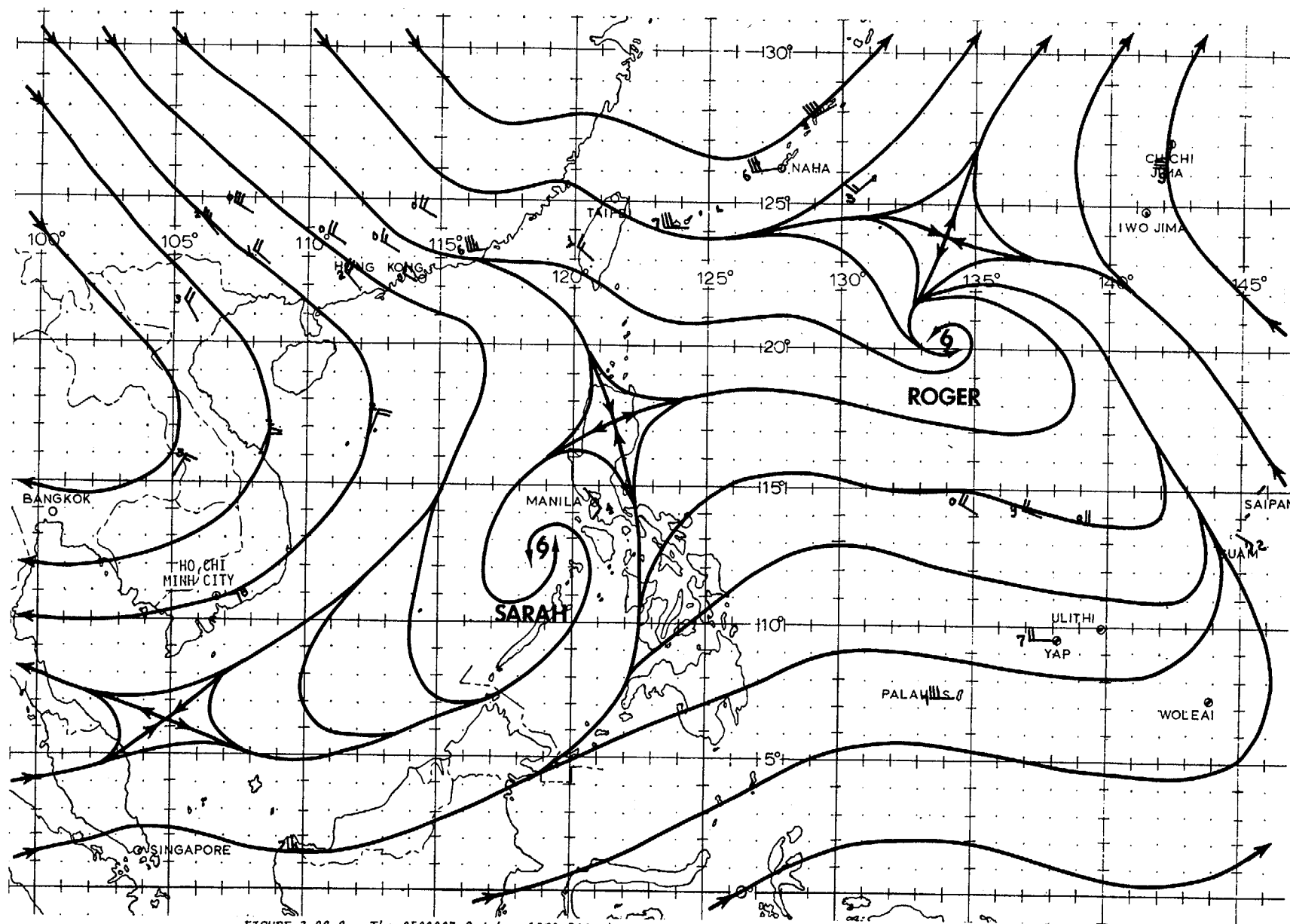
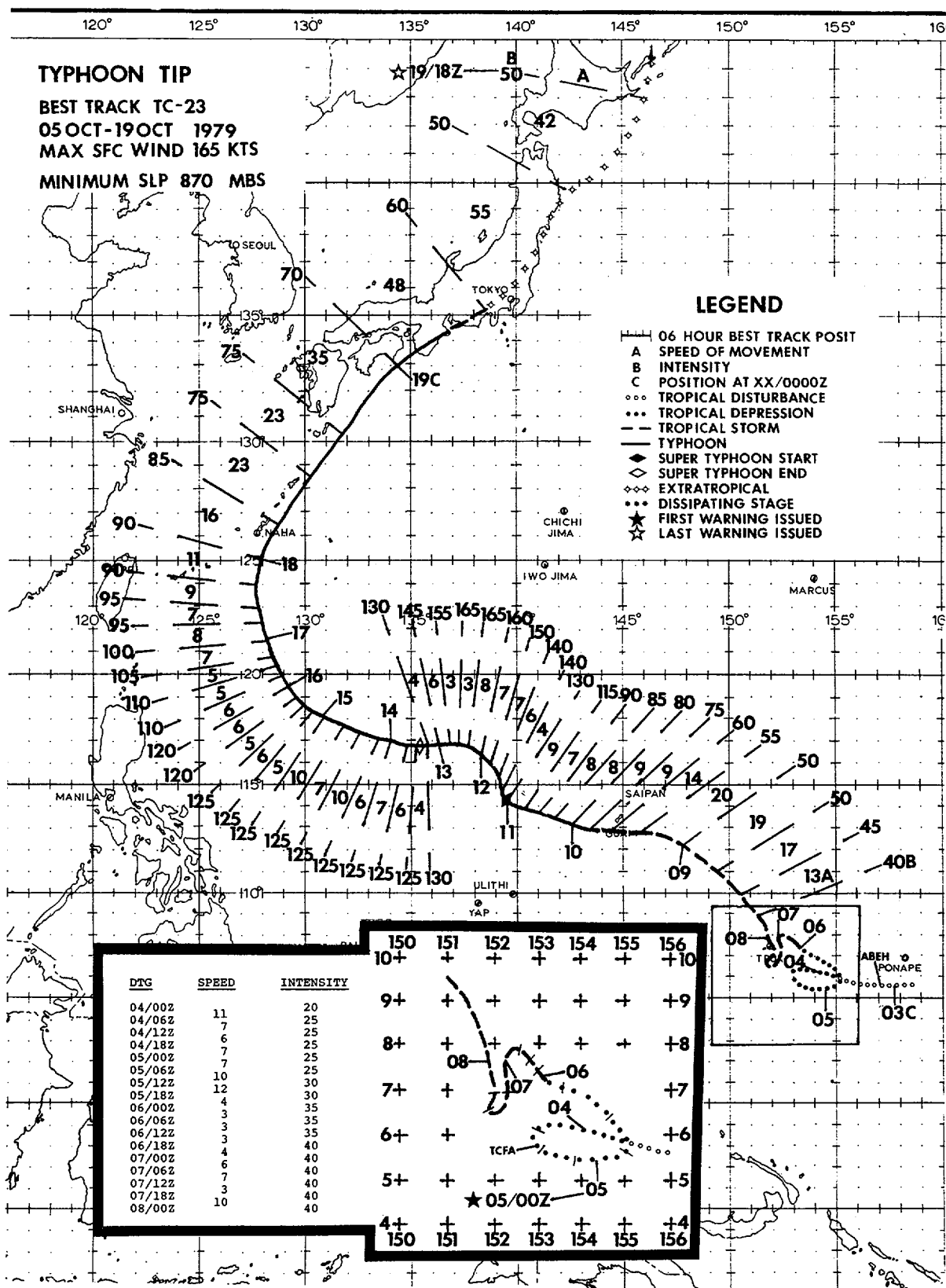


FIGURE 3-22-2. The 050000Z October 1979 500 mb streamline analysis. Wind speeds are in knots.



Super Typhoon Tip was the most significant typhoon of the 1979 season, and possibly the most significant tropical cyclone this century. Forty aircraft reconnaissance missions were flown on Tip, which produced 60 fixes, and thus made it one of the most closely watched cyclones in recent memory. Aircraft and synoptic data showed that Tip achieved the lowest sea-level pressure ever observed in a tropical cyclone (870 mb) and also had the largest circulation pattern on record (nearly 1200 nm (2222 km) in diameter).

Satellite and synoptic data during the early part of October revealed an active monsoon trough that extended from the Marshall Islands through the Caroline Islands to Luzon. Three distinct circulations developed in this trough: One near Manila, which would become Typhoon Sarah; another southwest of Guam, which would become Tropical Storm Roger; and the last between Truk and Ponape, which was destined to become Super Typhoon Tip.

It is not possible to discuss the development of Tip without, at the same time, examining the development of TS Roger. The surface analysis for 030000Z showed the three circulations in the monsoon trough with strong cross-equatorial flow, most of which was feeding into TS Roger. This situation was enhanced, in part, by an extratropical trough north of Roger over Southern Japan. The split in the surface flow pattern near Guam tended to keep Tip from developing rapidly while southeast of Guam. The upper-level analysis at the same time showed a large anticyclone north of Guam in close association with TS Roger and a developing TUTT cell about 300 nm (556 km) east of Marcus Island. The TUTT cell was moving slowly westward. Only strong upper-level northeasterlies existed over Truk and Ponape.

The satellite signature of the tropical disturbance near Truk continued to show improvement despite the initially unfavorable upper-air pattern. A Tropical Cyclone Formation Alert was issued at 040900Z, when a reconnaissance aircraft found a closed surface circulation about 120 nm (222 km) southeast of Truk with a MSLP of 1003.9 mb and a maximum observed surface wind of 25 kt (13 m/sec).

A reconnaissance aircraft fixed the disturbance the following day about 100 nm (185 km) southeast of the previous position. Based on indications of continual development, the first warning on TD 23 was issued at 050000Z. Although the surface pressure did not drop significantly, the observed surface winds did increase, and as a result, TD 23 was upgraded to Tropical Storm Tip at 060000Z.

During the period from 050000Z to 071800Z, TS Tip gave the JTWC forecasters a striking example of what the term "erratic movement" really means. TS Tip first executed a cyclonic loop southeast of Truk, then accelerated to the northwest, only to stall and meander to a position south of Truk. It was difficult to keep track of

TS Tip's surface position during this period. The best track is based almost entirely on aircraft surface positions, because the satellite fixes were based on upper-level outflow centers, and even the 700 mb center, as observed by aircraft reconnaissance, was considerably displaced from the surface center. Changes in the surface wind direction reported by Truk assisted JTWC in monitoring TS Tip during this period of erratic behavior.

Post-analysis shows that Tip's slow development and early erratic behavior are related to the weak, yet extensive circulation patterns that were associated with TS Roger. While near Truk, TS Tip was still competing with TS Roger for strong southerly surface inflow and, until the 8th, was coming out second best. During the period of erratic movement, JTWC continued to forecast a northwestward track with passage south of Guam. These forecasts were based primarily on the mid-level steering winds observed at Guam and obtained by the reconnaissance aircraft. These fairly strong winds were from the southeast and were expected to steer Tip toward Guam. However, at this stage of development, Tip was evidently too far south of this wind band and the steering in the immediate vicinity of Tip remained weak.

On 8 October, the expected northwest movement began. Roger was far to the north becoming extratropical, and the southerly winds that had been flowing north began to veer toward Tip. The TUTT cell earlier near Marcus Island migrated to a position northwest of Guam, affording Tip an excellent outflow channel to the north. Synoptic and subsequent aircraft data revealed that the southeasterly mid-level winds finally began to influence TS Tip, and the 080208Z aircraft fix confirmed that Tip was heading toward Guam at approximately 13 kt (24 km/hr). The minimum sea level pressure dropped to 995 mb and surface winds were 40 kt (21 m/sec).

Tropical Storm Tip continued to intensify and accelerate, eventually to 20 kt (37 km/hr) as he headed toward Guam. Until 6 hours before reaching Guam, Tip's persistence track and JTWC's forecasts indicated that he would pass directly over the center of the island. Six hours before expected landfall, however, reconnaissance aircraft and radar positions from Andersen AFB showed that TS Tip had turned to the west. Tip actually passed south of Guam, reaching CPA at about 25 nm (46 km) south of the southern end of the island at 091015Z. Maximum winds of 48 kt (25 m/sec) with gusts to 64 kt (33 m/sec) were recorded at the Naval Oceanography Command Center on Nimitz Hill. Andersen AFB recorded 6.5 inches of rain between 081800Z and 091800Z, and an additional 2.61 inches between 091800Z and 091900Z.

Shortly after passing Guam, Tip reached typhoon strength and continued on a basic west-northwest track. The analyses over the next few days showed that Typhoon Tip was moving into an area of strong upper-level divergence which appeared to cover most of



the western Pacific. Rapid intensification was forecast based upon the favorable upper-level pattern and the continued drop in surface pressure as observed by the reconnaissance aircraft. Intensification was much more rapid than expected, however, as the pressure between the 9th and the 11th dropped 98 mb to 898 mb. Tip reached super typhoon strength at that time with maximum winds of 130 kt (67 m/sec) reported by aircraft reconnaissance. The surface analyses revealed that the circulation pattern associated with Typhoon Tip had increased to a diameter of 1200 nm (2222 km) which broke the previous record of 720 nm (1333 km) set by Typhoon Marge in August 1951.

Super Typhoon Tip intensified still further, and at 120353Z, a reconnaissance aircraft recorded the lowest sea-level pressure ever observed in a tropical cyclone: 870 mb. This was 6 mb lower than the previous record set by Super Typhoon June in November 1975. The 700 mb height was 1944 meters and the 700 mb temperature within the eye was an exceptionally high 30° C (Fig. 3-23-1). The Aerial Reconnaissance Weather Officer (ARWO) on that particular mission remarked that "...one unusual feature was the spiral striations on the wall cloud. It looked like a double helix spiraling from the base of the wall cloud to the top, making about two revolutions in

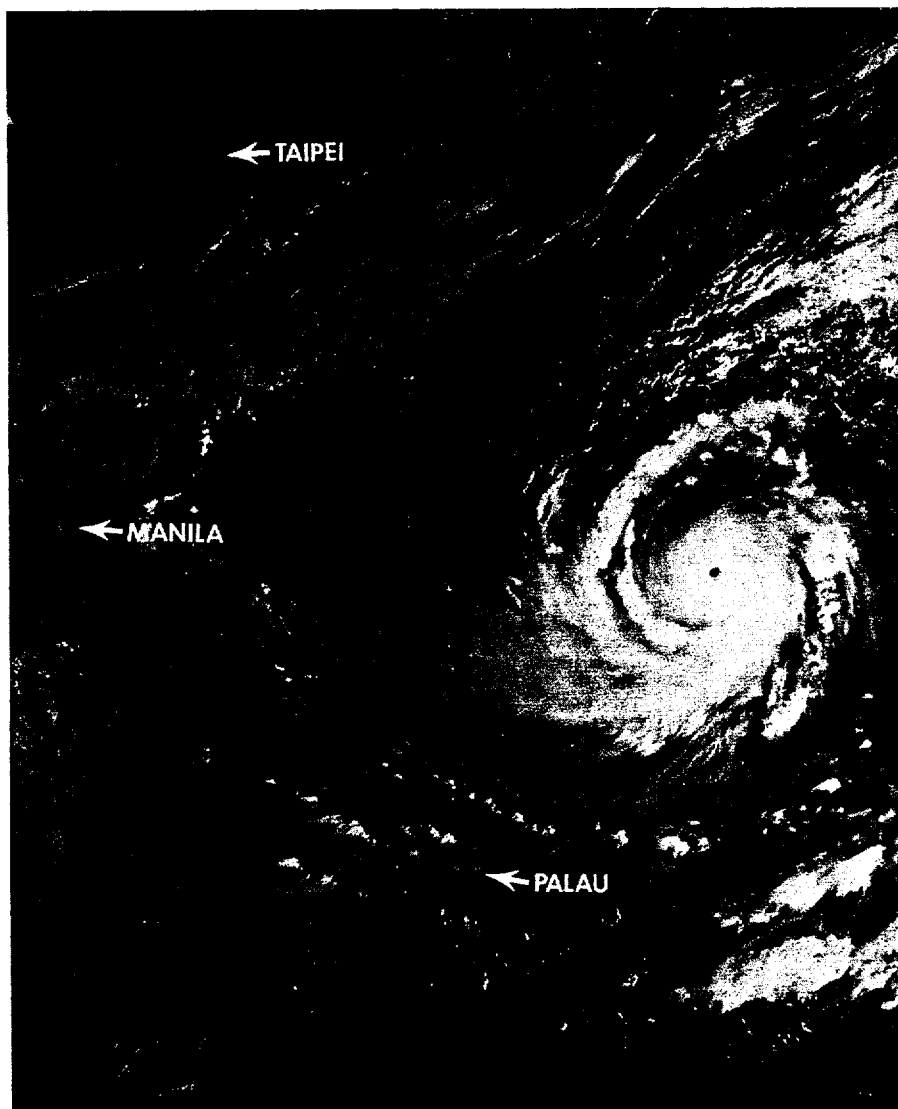


FIGURE 3-23-1. Super Typhoon Tip shortly before the record MSLP of 870 mb was observed by reconnaissance aircraft, 12 October 1979, 0012Z. (DMSF imagery).

climbing."<sup>1</sup> Tip maintained super typhoon strength for the next 54 hours while moving to the northwest at between 3 and 7 kt (6 and 13 km/hr). Estimated maximum wind intensity of 165 kt (85 m/sec) was reached at 120600Z.

The immense circulation pattern associated with Typhoon Tip extended from the surface through 500 mb (and probably higher) and essentially split the subtropical mid-tropospheric ridge south of Japan. This would have allowed an average typhoon to recurve sharply to the north, but Tip was an atypical system and the northwestward movement persisted for the next three days.

Steering forecast aids were useless during this period because they merely steered Tip in his own large storm-induced flow. Persistence and climatology became the primary forecast aids during this stage in Tip's life.

From the 13th to the 17th, the radius of surface and gradient-level 30 kt (15 m/sec) or greater winds extended over 600 nm (1111 km) from Typhoon Tip's center. The radius of over 50 kt (26 m/sec) winds was over 150 nm (278 km) (Fig. 3-23-2). The aircraft reconnaissance data likewise showed that 700 mb winds of 105 kt (54 m/sec) existed more than 120 nm (222 km) from Tip's center during this period (Fig. 3-23-3).

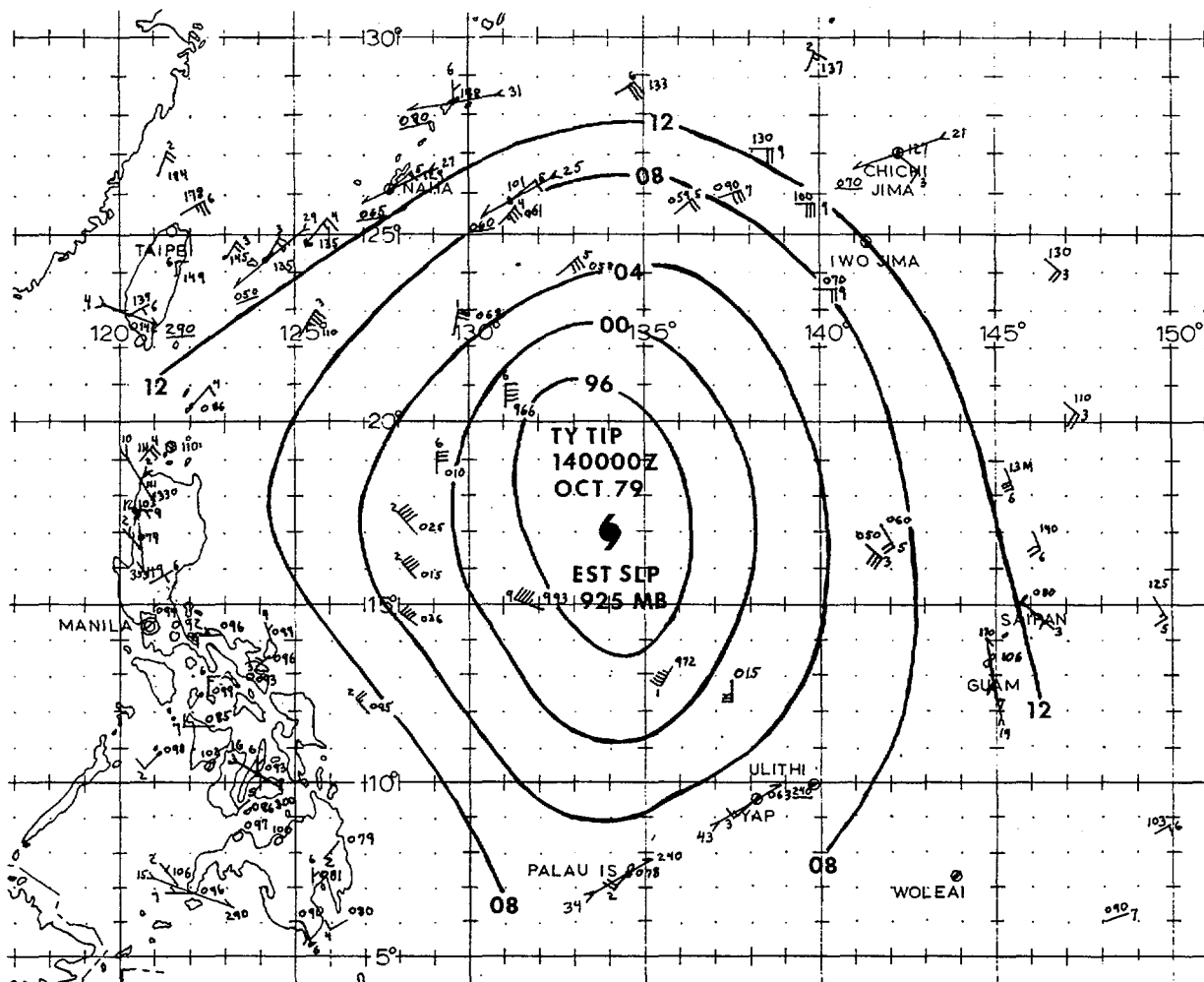


FIGURE 3-23-2. The 140000Z October 1979 surface (—) / gradient-level (ddd) wind data and pressure analysis in the vicinity of Super Typhoon Tip. Wind speeds are in knots.

<sup>1</sup>PATRICK W. GIESE, Capt, USAF: Mission ARWO.

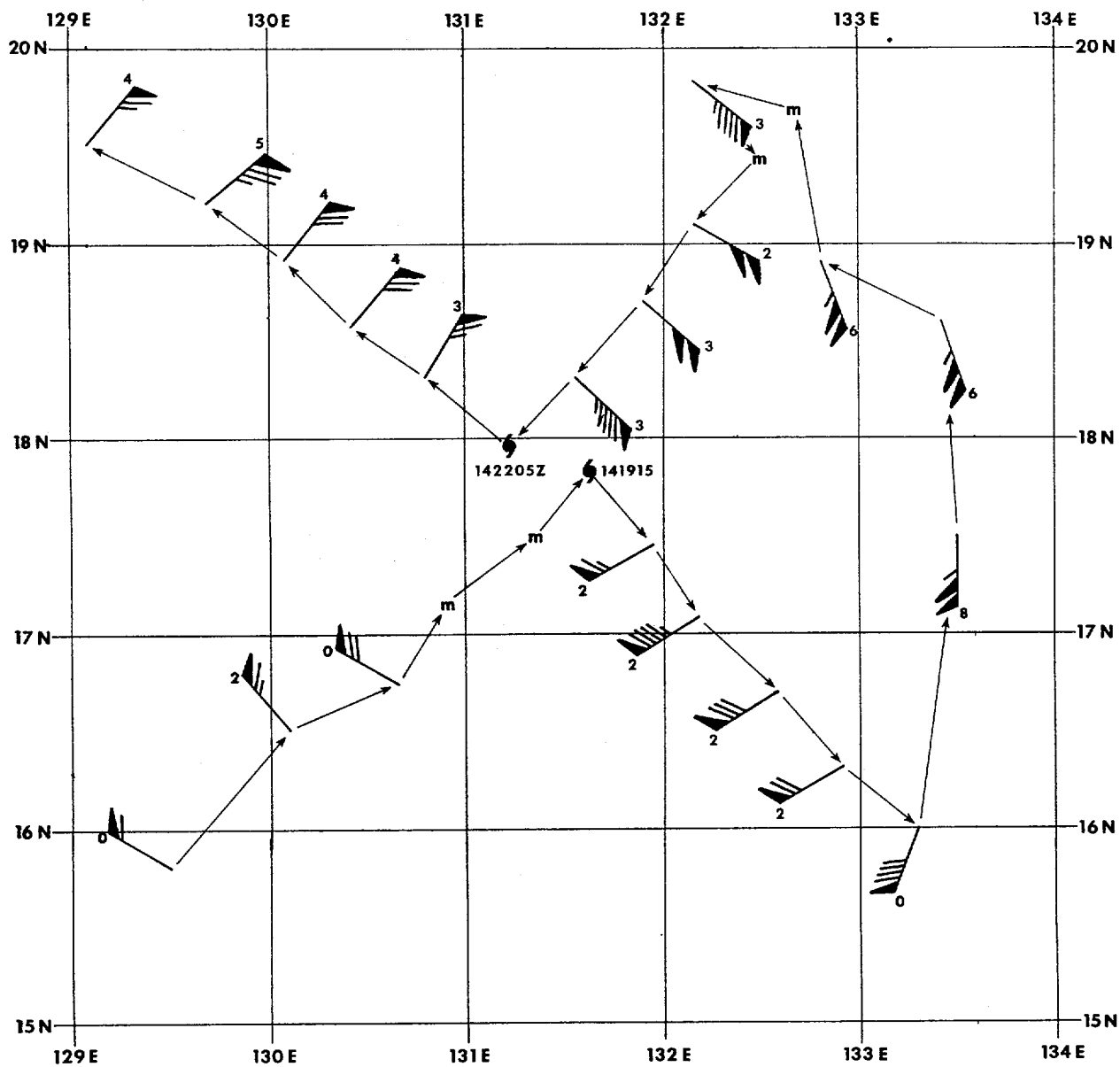


FIGURE 3-23-3. Plot of aircraft reconnaissance data from the 26th mission into Super Typhoon Tip on 15 October 1979. Tip's positions were fixed at 141915Z and 142205Z. Wind barbs are the measured 700 mb winds. The tens digit of the wind direction is also plotted with the wind barbs. An "m" indicates no 700 mb wind data available.

After the 17th, Tip began to weaken as the large circulation pattern began to shrink. This, together with the effects of a mid-level trough moving toward Japan from China, caused Tip to begin tracking northward. By the 18th, he was accelerating to the northeast under the influence of the increased mid-level southwesterlies.

During recurvature, Tip passed within 35 nm (65 km) of Kadena AB on Okinawa, which reported maximum sustained winds of 38 kt (20 m/sec) with gusts to 61 kt (31 m/sec).

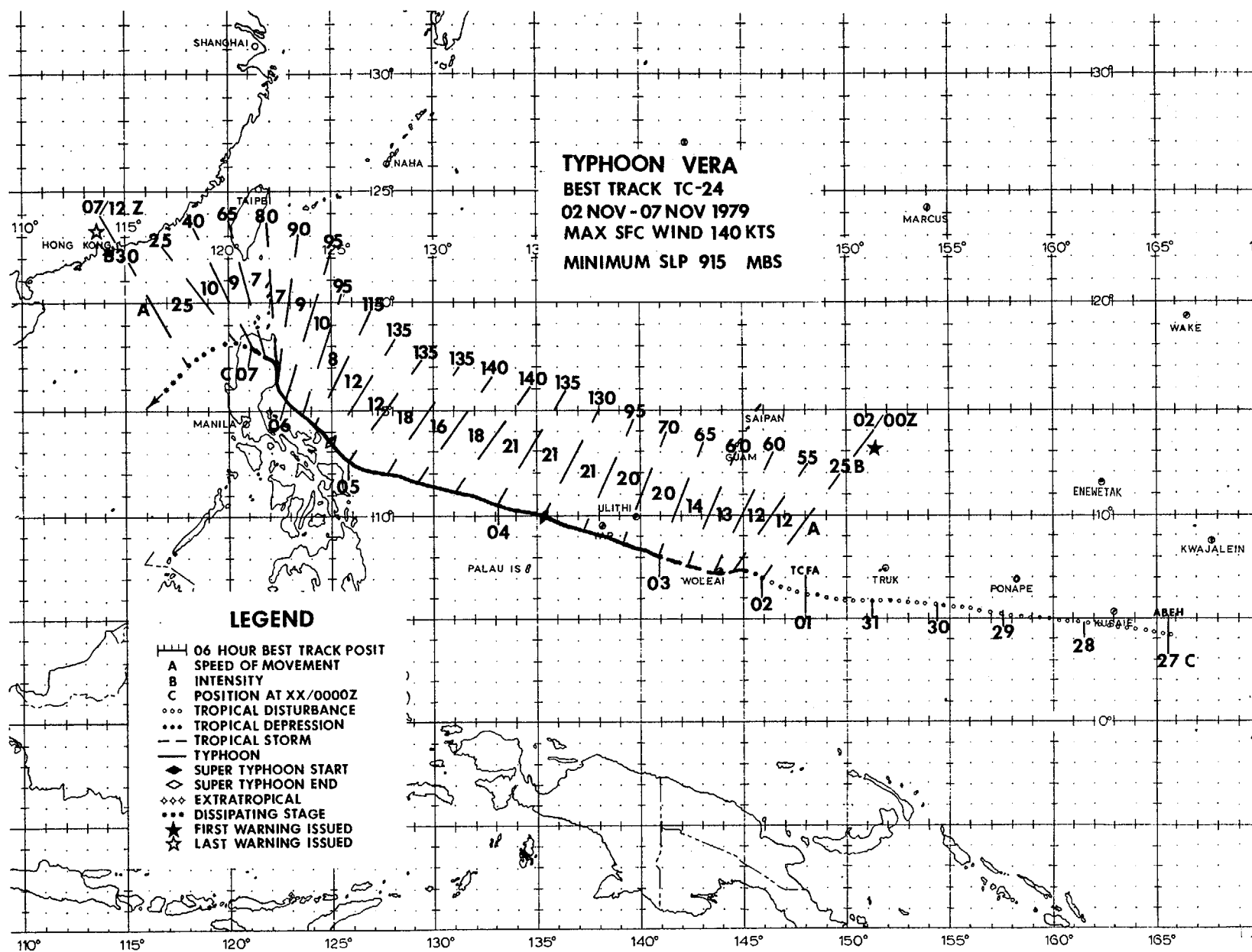
At approximately 190100Z, after reaching a forward speed of between 35 and 45 kt (65 and 83 km/hr), Typhoon Tip, with maximum winds of 70 kt (36 m/sec), made landfall on the Japanese island of Honshu, about 60 nm (111 km) south of Osaka. Synoptic and radar data from stations on the island showed that Tip maintained a speed in excess of 45 kt (83 km/hr) as he passed to the north of Tokyo and eastward into the Pacific Ocean. According to satellite imagery, Tip completed extratropical transition over Honshu.

The extratropical low pressure center (the remnants of Tip) maintained winds of storm force, 48 kt (25 m/sec), until the 21st when it moved to a position east of Kamchatka and finally began to fill rapidly.

The majority of the severe damage occurred in Japan where the agricultural and fishing industries sustained losses into the millions of dollars. Flooding from Tip's rains also breached a fuel retaining wall at Camp Fuji, west-northwest of Yokosuka. The fuel caught fire causing 68 casualties, including 11 deaths, among the U.S. Marines stationed there.

Considering the size and strength of Super Typhoon Tip, the Western Pacific fared well. Luckily, the maximum intensity was reached while the system was still far from any inhabited areas. The potential for mass destruction was always there, but from a strictly meteorological standpoint, Tip was also a thing of great beauty. One of the Aerial Reconnaissance Weather Officers stated, shortly after she returned from a mission, that "...the second penetration was beyond description. This is unquestionably the most awe-inspiring storm I have ever observed. In the 2½ hours that transpired between the first and second fixes, the moon had risen sufficiently to shine into the eye through an 8 nm clear area at the top of the eyewall. To say it was spectacular is totally inadequate...'awesome' is a little closer."<sup>1</sup>

<sup>1</sup>CAROL L. BELT, 1LT, USAF: Mission ARWO.



Vera, the fourth and final super typhoon of 1979, originated in an active near-equatorial trough (NET) which extended through the Caroline and Marshall Islands. Vera was first analyzed as a weak surface circulation 100 nm (185 km) southeast of Ponape on 27 October and was included on JTWC's Significant Tropical Weather Advisory (ABEH PGTW) for the next 4 days as it remained in the NET. Low-level inflow during this period was split between several weak eddies.

By 300000Z, synoptic data indicated that the low-level inflow was now concentrated into the developing cyclone. Meanwhile, the convective activity increased rapidly over a 24-hour period from 310000Z to 010000Z. A Tropical Cyclone Formation Alert was issued at 010000Z November based on increased upper-level outflow and a continued decrease in surface pressure.

Aircraft reconnaissance at 012100Z found an ill-defined circulation center with a central pressure of 1004 mb and estimated surface winds of 15 kt (8 m/sec). Numbered warnings began at 020000Z based on an improved satellite signature. Rapid intensification occurred, and TD 24 was upgraded to Tropical Storm Vera 6 hours later. Vera continued to intensify, reaching typhoon strength by 0000Z on 3 November while 190 nm (352 km) south-southeast of Yap. At this time, the 200 mb analysis revealed that a large upper-level anticyclone, previously located northwest of Vera at 010000Z, was weakening and was no longer restricting Vera's outflow to the north. By 020000Z, the anticyclone situated over Vera had become the dominant upper-level synoptic feature over the western Pacific.

From the time of the first warning until her approach to the Philippines northeast of Samar, Vera moved on a virtually straight west-northwest track. The major influence on her movement was the unusually strong mid-tropospheric subtropical ridge over the western Pacific. The strength of the easterly current south of the ridge steered Vera at forward speeds of 20 to 22 kt (37 to 41 km/hr)--almost twice the climatological average--as she passed 35 nm (65 km) south of Yap. As a result, although JTWC's forecast tracks were consistent and accurate, forecast forward speeds lagged behind Vera's actual speeds. The underestimates were considerable during the early stages of acceleration.

Vera continued to intensify during her west-northwestward acceleration and reached super typhoon intensity only 18 hours after being upgraded to a typhoon. Reconnaissance aircraft reports indicated Vera maintained super typhoon strength for over 24 hours before weakening as she approached Catanduanes Island. The peak wind reported on Catanduanes Island was 50 kt (26 m/sec) at 051200Z as Vera passed just off the coast.

The island chain began restricting low-level inflow as Vera continued northwestward toward northern Luzon. Vera made landfall north of Tarigdig Point packing winds of 90 kt (46 m/sec).

After landfall, the onset of enhanced low-level northeasterly flow over the Taiwan Straits coupled with strong upper-level southwesterlies over the Philippines resulted in vertical disorganization and rapid weakening of Vera. Radar and aircraft reports indicated the low-level circulation continued to track northwestward over the Cagayan River valley and exit into the South China Sea near Culili Point south of Laoag. The upper-level circulation sheared off near Tuguegarao and was tracked using satellite imagery northward over Aparri then east-northeastward into the Philippine Sea. Surface synoptic and ship reports at 070000Z indicated that a secondary surface center existed near Baguio. At the same time, the primary center was crossing the Cordillera Central Mountain range 95 nm (176 km) to the north (Fig. 3-24-1).

After exiting into the South China Sea, the strong northeast monsoon flow accelerated Vera southwestward, and the final warning was issued at 1200Z on the 7th downgrading Vera to a tropical depression.

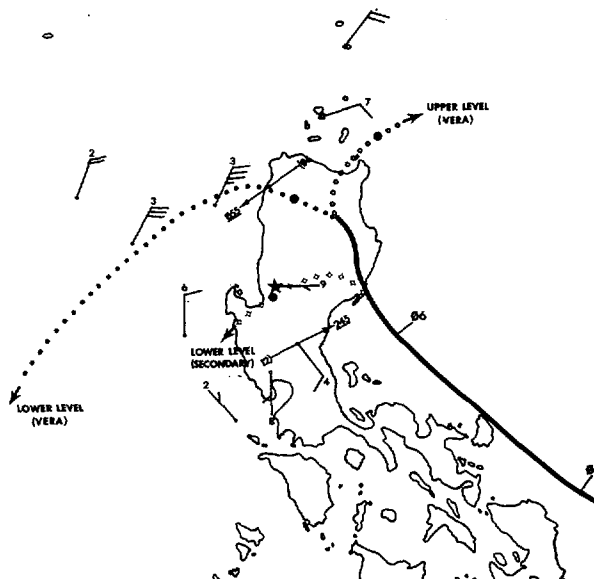
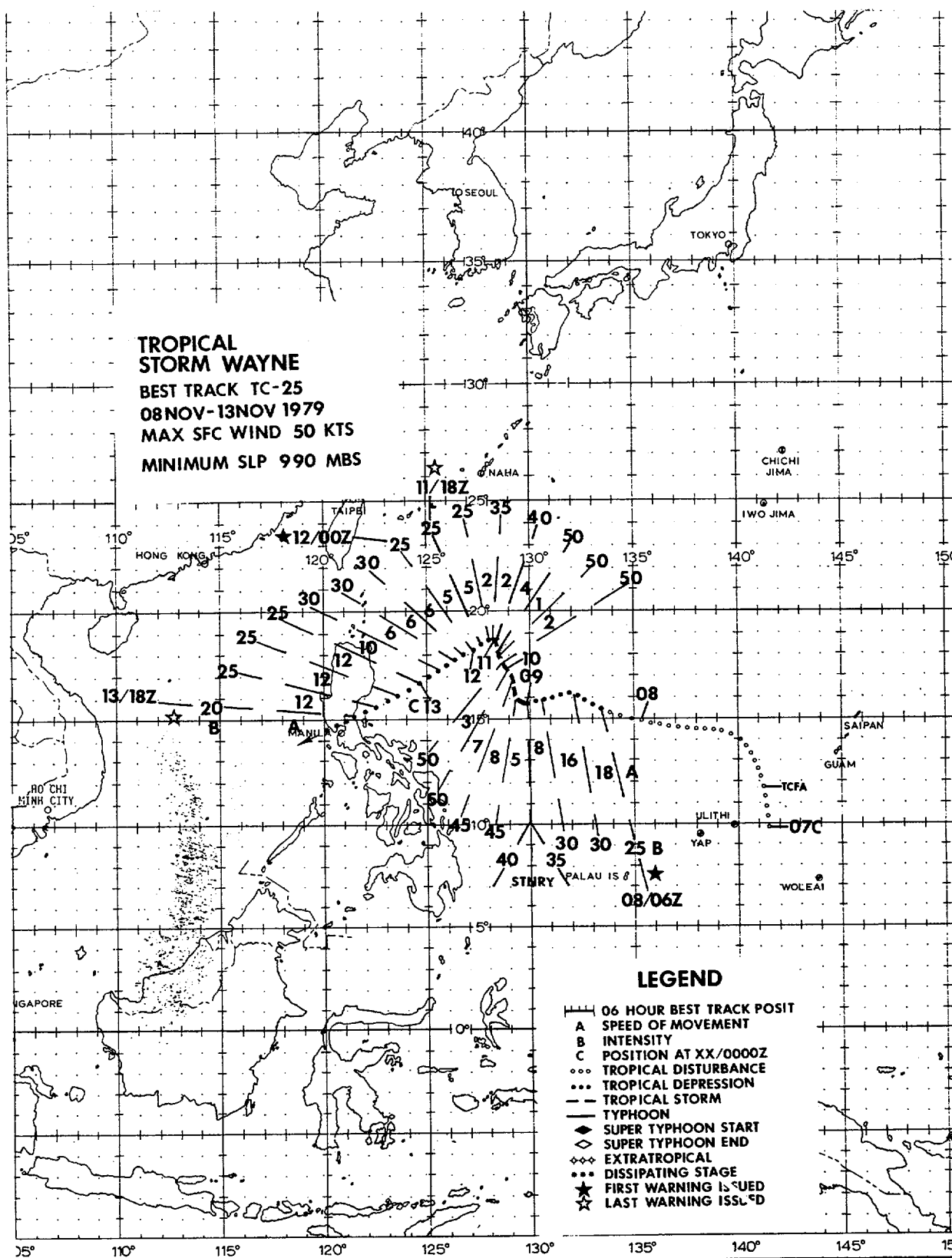


FIGURE 3-24-1. Tracks of low-level and upper-level centers after the upper-level sheared off over northern Luzon. Synoptic and ship reports at 070000Z November indicate secondary low-level center near Baguio (WMO 98328) (indicated by a star). The 070000Z center positions are indicated by solid dots. Wind speeds are in knots.



# TROPICAL STORM WAYNE

Tropical Storm Wayne was first detected as a mid-level circulation on satellite imagery in early November. Figure 3-25-1 shows the broad cloud structure associated with the system. Aircraft reconnaissance around this period showed that the disturbance was most developed at mid-levels. Wayne moved northward initially and began developing a more definitive surface circulation which became evident in synoptic data on 7 November. Wayne lasted only a relatively short time, but he still proved to be one of the more difficult storms to forecast for 1979.

JTWC's first forecasts called for recurvature. They were based on the 080000Z November 500 mb synoptic situation which showed a weakness in the subtropical ridge with westerlies extending south to 23°N latitude. Steering flow at all levels, however, was not consistent and strong low-level easterlies prevented Wayne from recurving toward the east. On 9 November, an extratropical system with accompanying surface frontogenesis developed north of Wayne. This caused a break in the otherwise persistent easterly flow and Wayne began to track northward. JTWC forecasts again reflected recurvature and called for early dissipation due to the strong shear from low-level easterlies and upper-level westerlies. The extratropical system moved rapidly eastward bypassing Wayne. By 11 November, strong northeasterlies had once again been established, and Wayne turned back to the west, ultimately, tracking west-southwest toward the central

Philippines. At the same time, strong shear did weaken Wayne as it tracked toward the Philippines (Figure 3-25-2) and dissipation occurred as he made landfall over Luzon.

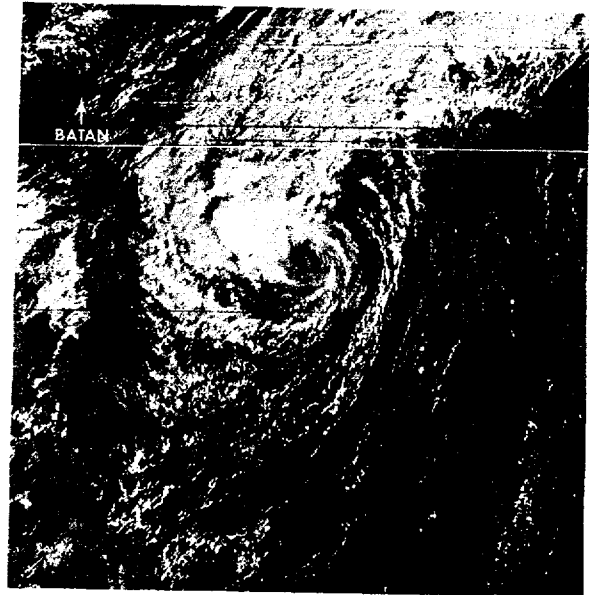


FIGURE 3-25-2. Tropical Storm Wayne weakening due to strong shear as it approached the Philippines, 12 November 1979, 0100Z. (DMSP imagery)

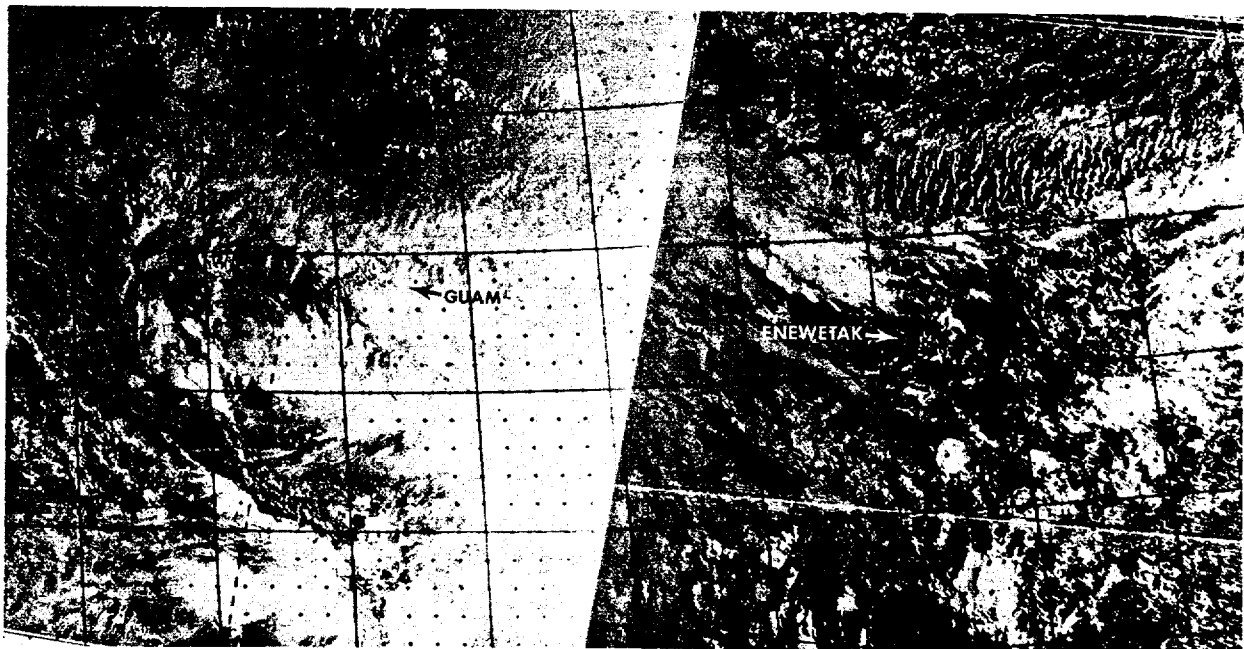
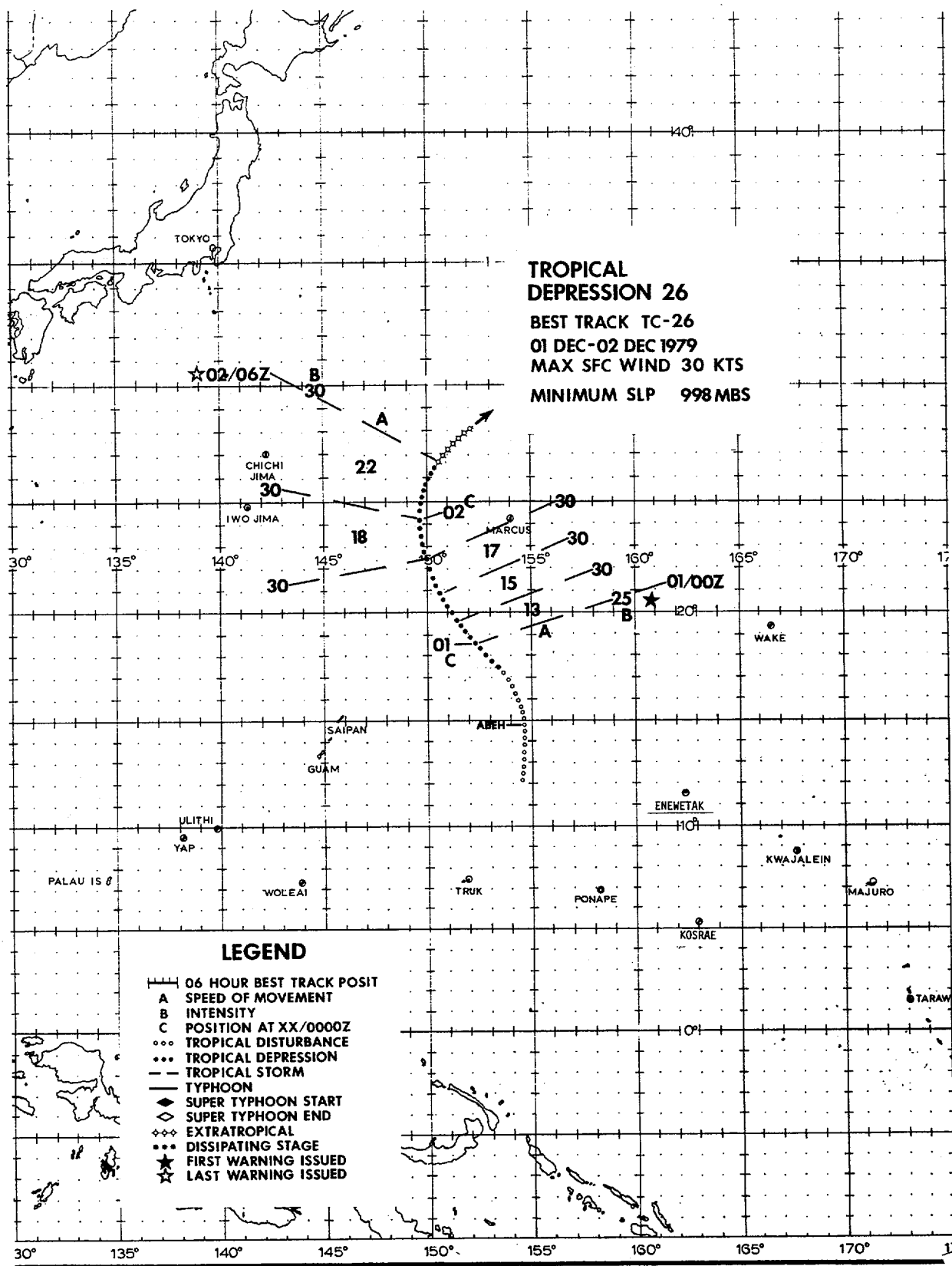


FIGURE 3-25-1. Disturbance stage of Tropical Storm Wayne when the system was mainly a mid-level circulation, 6 November 1979, 1208Z. (DMSP imagery)





# TROPICAL DEPRESSION 26

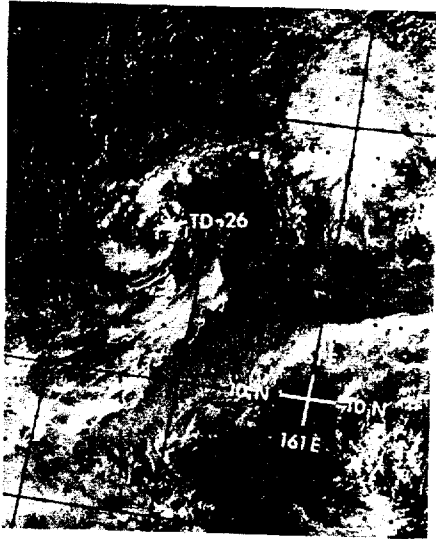


FIGURE 3-26-1. Tropical Depression 26 developed north-northeast of the Truk Islands and appeared to be the surface reflection of a mid-level circulation. Surface data suggest the existence of a weak circulation 400 nm (741 km) northeast of Tropical Depression 26 and a broad circulation (Typhoon Abby) to the southeast, 29 November 1979, 2255Z. [DMSP imagery]

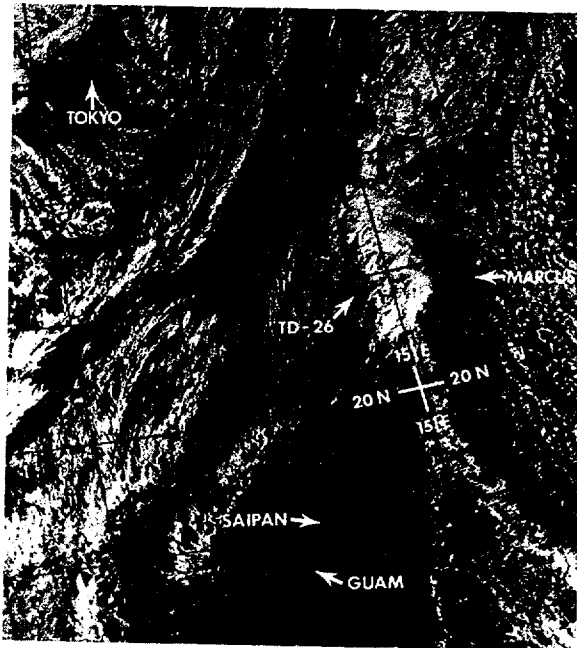


FIGURE 3-26-3. Tropical Depression 26 passed west of Marcus Island and merged with an extratropical frontal boundary. Tropical Depression 26 sheared in the vertical with the low-level exposed surface circulation remaining on the western edge of the convection, 2 December 1979, 0036Z. [DMSP imagery]

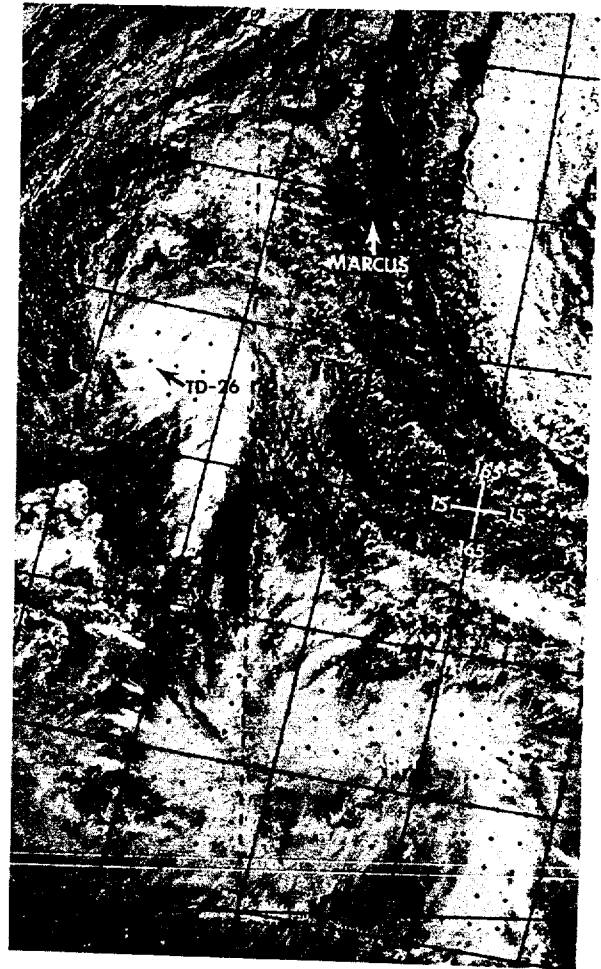


FIGURE 3-26-2. Tropical Depression 26 developed an identifiable surface circulation and intensified as it tracked north-northwestward. A ship, transiting the area, passed through the storm center and reported 35 kt (18 m/sec) winds in heavy showers. Based on synoptic data, the first warning was issued on Tropical Depression 26, but 35 kt-or-greater winds were never reported again. This photo shows Tropical Depression 26 at its maximum convective intensity, 30 November 1979, 2237Z. [DMSP imagery]

# TYPHOON ABBY

BEST TRACK TC-27

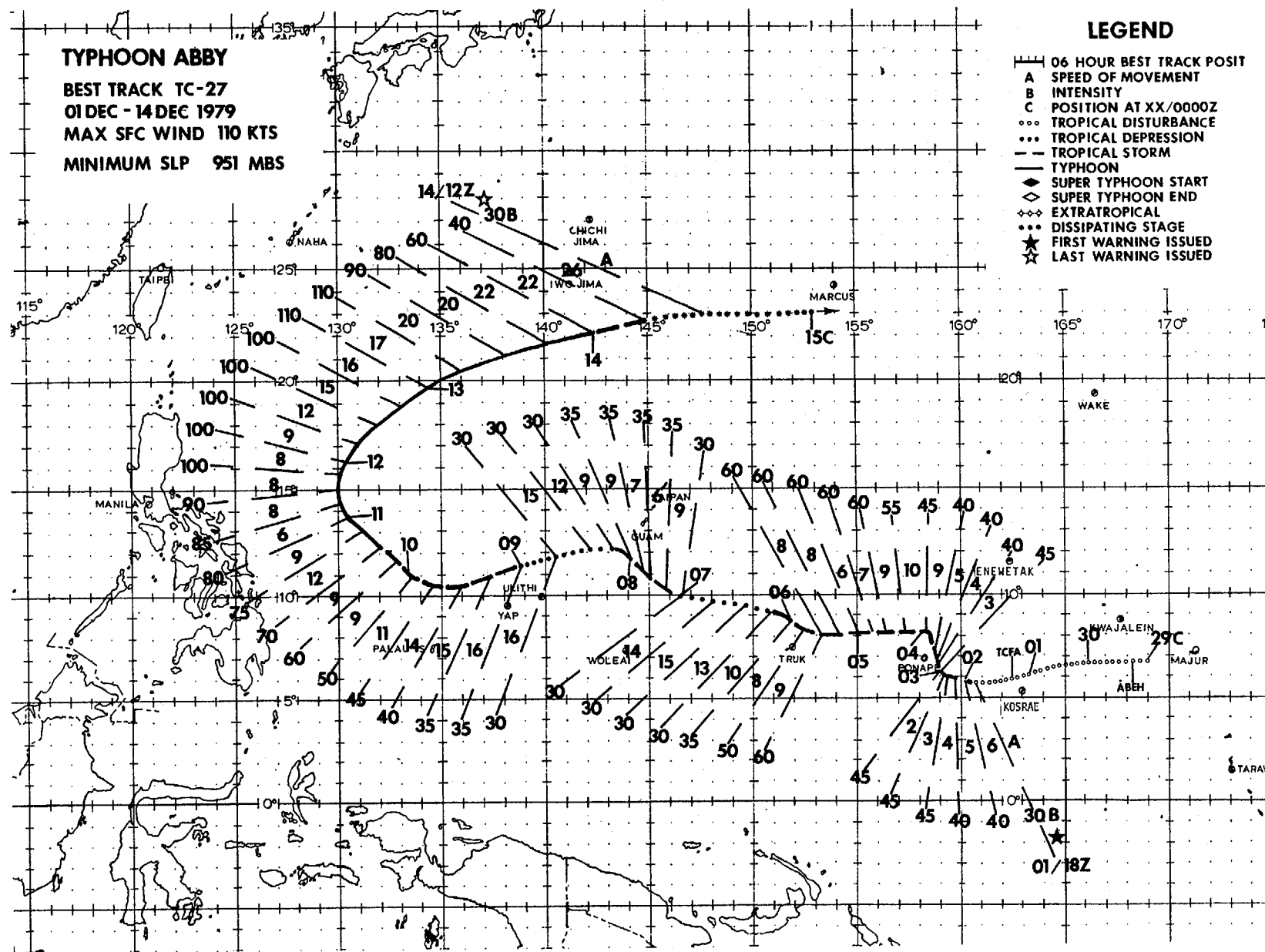
01 DEC - 14 DEC 1979

MAX SFC WIND 110 KTS

MINIMUM SLP 951 MBS

## LEGEND

- 06 HOUR BEST TRACK POSIT
- A SPEED OF MOVEMENT
- B INTENSITY
- C POSITION AT XX/0000Z
- ... TROPICAL DISTURBANCE
- ... TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◇◇ EXTRATROPICAL
- ... DISSIPATING STAGE
- ★ FIRST WARNING ISSUED
- ☆ LAST WARNING ISSUED



Abby, the last typhoon of the 1979 season, developed over the Marshall Islands during early December. Abby proved to be an unusual cyclone in several ways. Throughout much of Typhoon Abby's existence, Abby was not vertically aligned. Aircraft reconnaissance located the mid-level circulation center displaced as much as 55 nm (102 km) from the surface center. At one point, two centers were identified; a point to be discussed later. In addition, Abby fluctuated between tropical depression and tropical storm strength several times before reaching typhoon strength 10 days after formation.

Within 24 hours of the first warning, aircraft reconnaissance observed surface winds of 45 kt (23 m/sec) and a sea-level pressure of 996 mb. The surface and 700-mb centers were displaced by 12 nm (22 km). Abby continued to intensify to 60 kt (31 m/sec) on 4 October while increasing the displacement between the surface and 700-mb centers.

Abby deviated from a westward track to a north-northwestward track on 3 December with a reduced forward speed of movement. The temporary northward movement was associated with a deepening mid-tropospheric trough which moved rapidly northeastward away from Japan on 1 December. Abby resumed a westward track with increased forward speed after the trough axis passed east of Abby late on the 3rd.

All available information (climatology, analog aids, analyses and numerical forecasts) indicated continued intensification as Abby tracked towards Guam. This expected intensification was reflected in JTWC warnings during this period. However, the opposite occurred. As Abby moved west of Truk, she weakened to less than tropical storm strength. An upper tropospheric anticyclone north of Abby restricted Abby's outflow and resulted in the observed weakening (Fig. 3-27-1). By 7 December, Abby reintensified to minimum tropical storm strength as she moved westward and away from the influence of the restricting anticyclone. Abby then tracked west-northwestward under the influence of a mid-tropospheric long-wave trough oriented along 142E. As the trough moved east of Abby, the subtropical mid-tropospheric ridge again built eastward, providing a mechanism which steered Abby towards the west-southwest. During the 8th, Abby once again weakened to less than tropical storm strength and increased her forward speed of movement.

Abby was not vertically aligned from the issuance of the first warning through the 9th. On the 9th, aircraft reconnaissance making a supplemental fix at 0617Z observed that Abby possessed multiple 700 mb centers. By the time of entry into Abby for a levied 0830Z fix, only one well organized, intensifying center was found. The following is a storm mission summary by the Aerial Reconnaissance Weather Officer (ARWO), who made the double penetration into Abby: "This mission started out as a normal fix but ended

up being unusual. On our way inbound for the supplemental fix, there was no problem reading winds at flight level or on the surface. Winds were 20-25 kt the entire way. An area of thunderstorm activity became visible ahead of us. As we neared it, the doppler indicated that the 700 mb center was in the middle of the thunderstorm. Not eager to go find this out, we went back to find the surface center. Enroute, we saw surface winds in excess of 35 kt which led us to a fairly disorganized surface center just east of the main thunderstorm. Over it was a fairly small light and variable wind center. Radar showed little curvature in the shower pattern, but the surface winds did indicate a weak circulation existed at this first position. No weather existed to the east of our first fix, and this position was right on the JTWC forecast track. On the second fix, things had changed. As we came in the second time, we encountered considerable precipitation. Doppler and search radar indicated a center with a possible wall cloud forming considerably west of our first fix. Winds were stronger at flight level and we penetrated a wall cloud of about 80% coverage. When we broke through, we encountered our strongest winds at flight level. The surface center was under the eastern wall cloud with a small light and variable wind center at 700 mb centered in the eye. Lightning started in the eastern wall cloud and spread around the

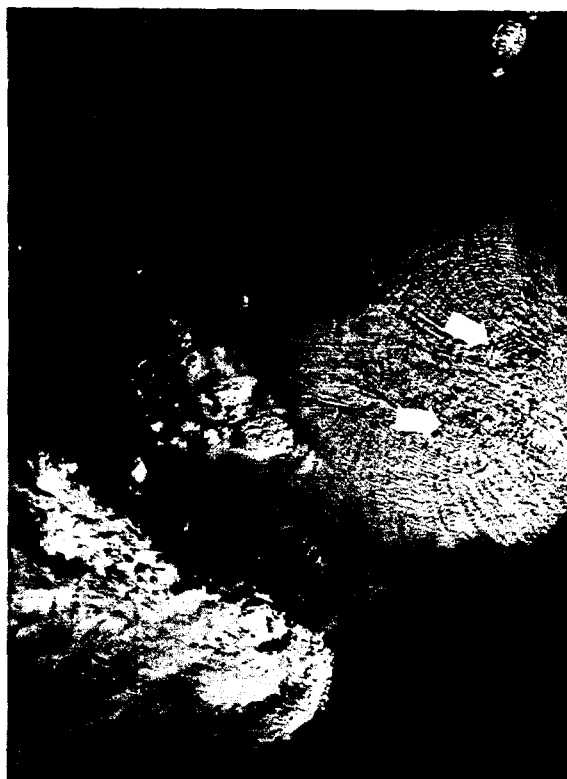
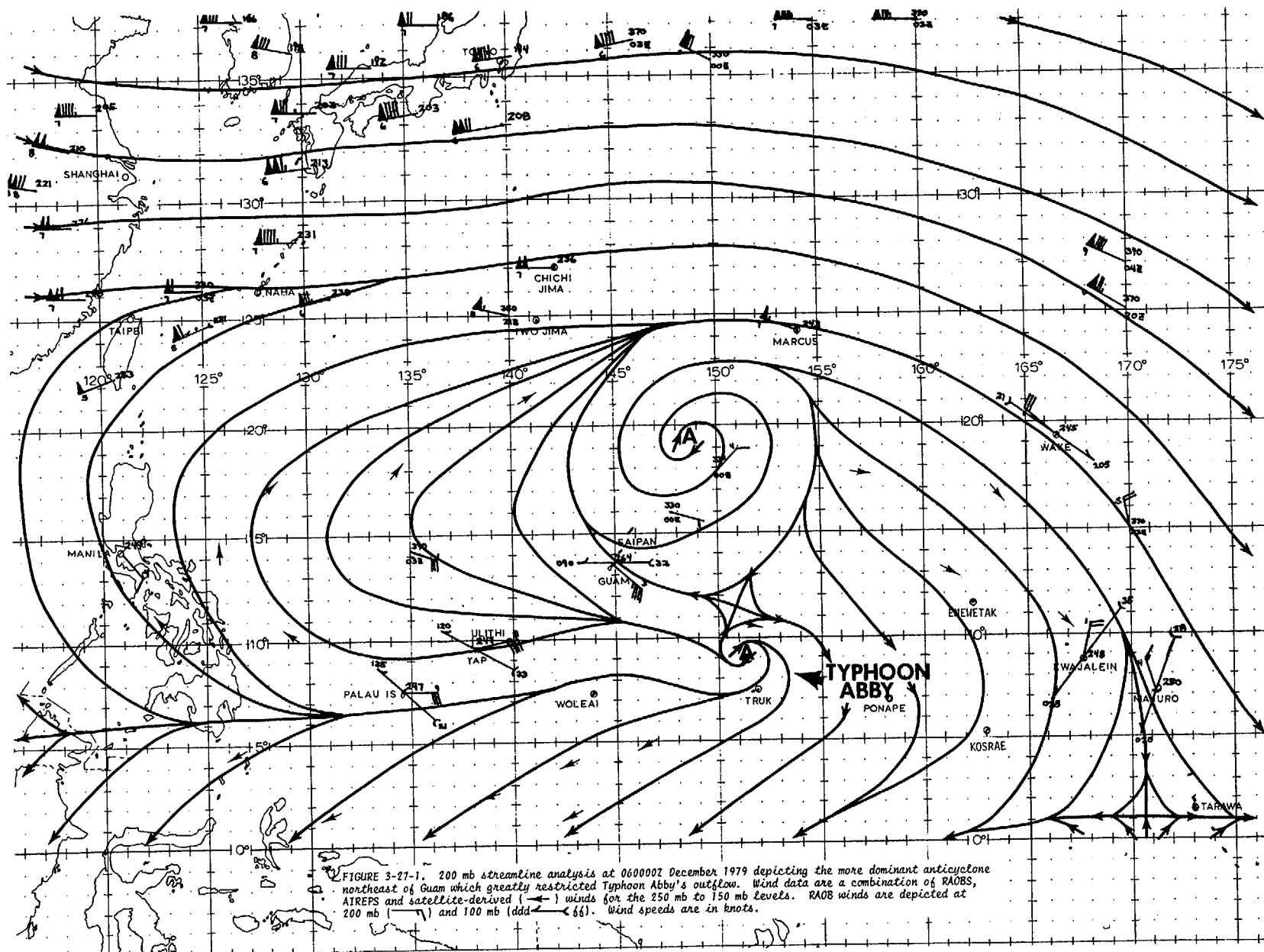


FIGURE 3-27-2. Typhoon Abby's two outflow centers are indicated by arrows, 9 December 1979, 0144Z. (DMSP imagery) Figure 3-27-1 is on next page.

FIGURE 3-27-1 is on following page.



eye. Our drop was made as close to the surface center as was possible and indicated a good 988 mb sea-level pressure. The 700 mb height was down 72 meters from the first fix. The positions were 85 miles apart causing me to believe that two centers existed for a short time with the latter becoming the predominate one. The pressure profile seems to indicate this theory...."<sup>1</sup> Satellite imagery at 090144Z also indicated the possible existence of multiple outflow centers (Fig. 3-27-2). While Abby was reorganizing into a single center, she began to reintensify to tropical storm strength. By the 10th, Abby had attained typhoon strength which made her the last typhoon of the decade.

A mid-tropospheric short-wave trough moved from mainland China into the Sea of Japan and deepened on the 10th. In response to the short-wave trough, the subtropical mid-tropospheric ridge again receded eastward north of Abby. The interaction of these two synoptic features allowed Abby to again track northwest. On the 11th, Typhoon Abby recurved in response to another mid-tropospheric short-wave trough, which extended further south than the trough on the 10th. This last trough in the series moved into the northern part of the South China Sea and deepened, causing Abby to finally follow a recurvature track.

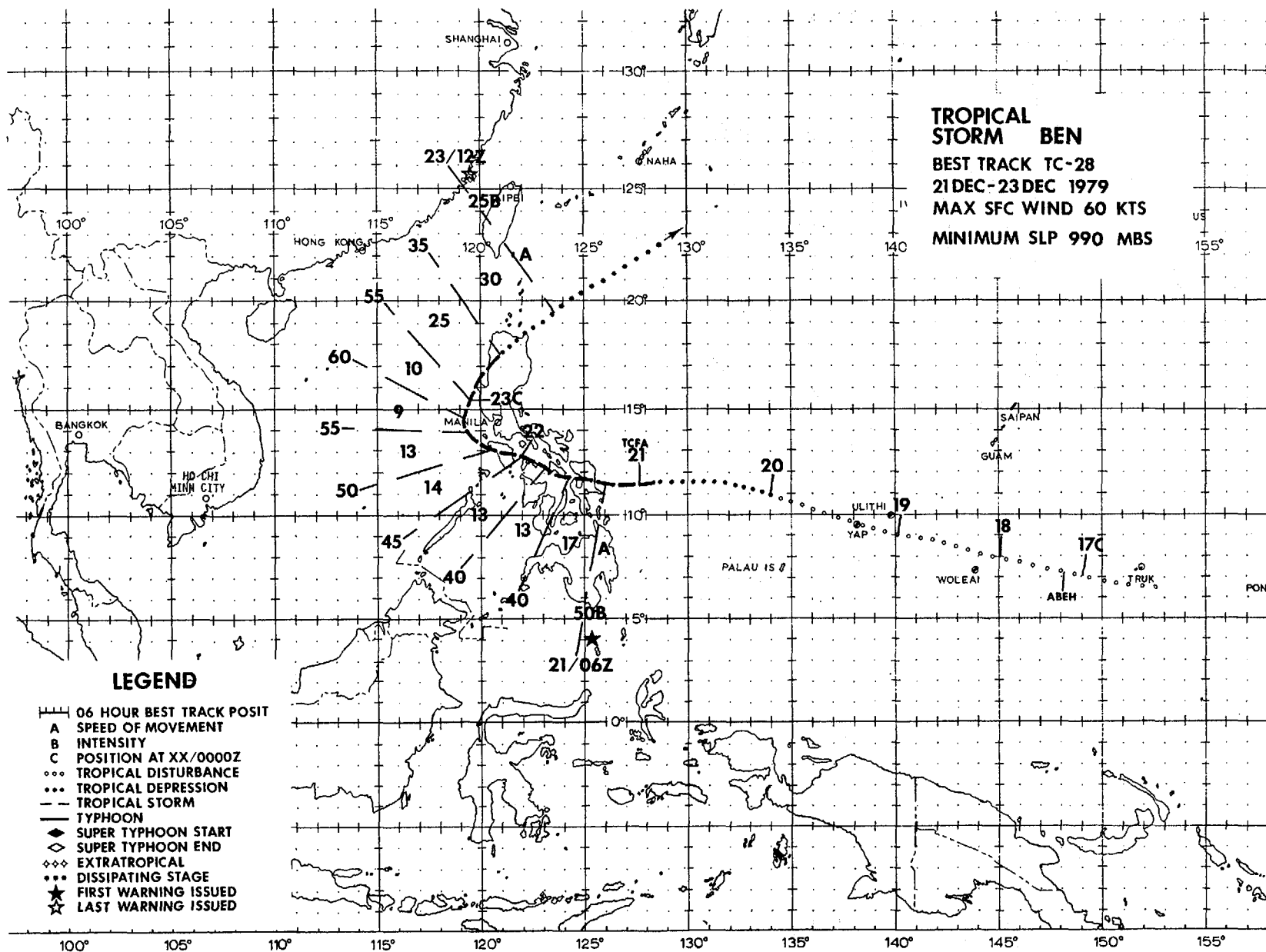
Typically, recurving typhoons have their maximum intensities either less than 12 hours after recurvature or prior to recurvature (Riehl, 1971). Abby, however, did not reach maximum intensity until 36 hours after recurvature. By 13 December, Typhoon Abby reached maximum intensity of 110 kt (57 m/sec) with a minimum sea-level pressure of 951 mb (Fig. 3-27-3). As Abby continued toward the east-northeast, she approached a regime of very strong westerlies in the middle-and upper-troposphere. The strong westerlies induced Abby's acceleration

and rapid weakening. Abby dissipated on the 14th due to strong vertical shear between the surface and middle levels.



FIGURE 3-27-3. Typhoon Abby just after recurvature, 12 December 1979, 0021Z. [DMSP imagery]

<sup>1</sup>CHARLES B. STANFIELD, Capt, USAF: Mission ARWO.



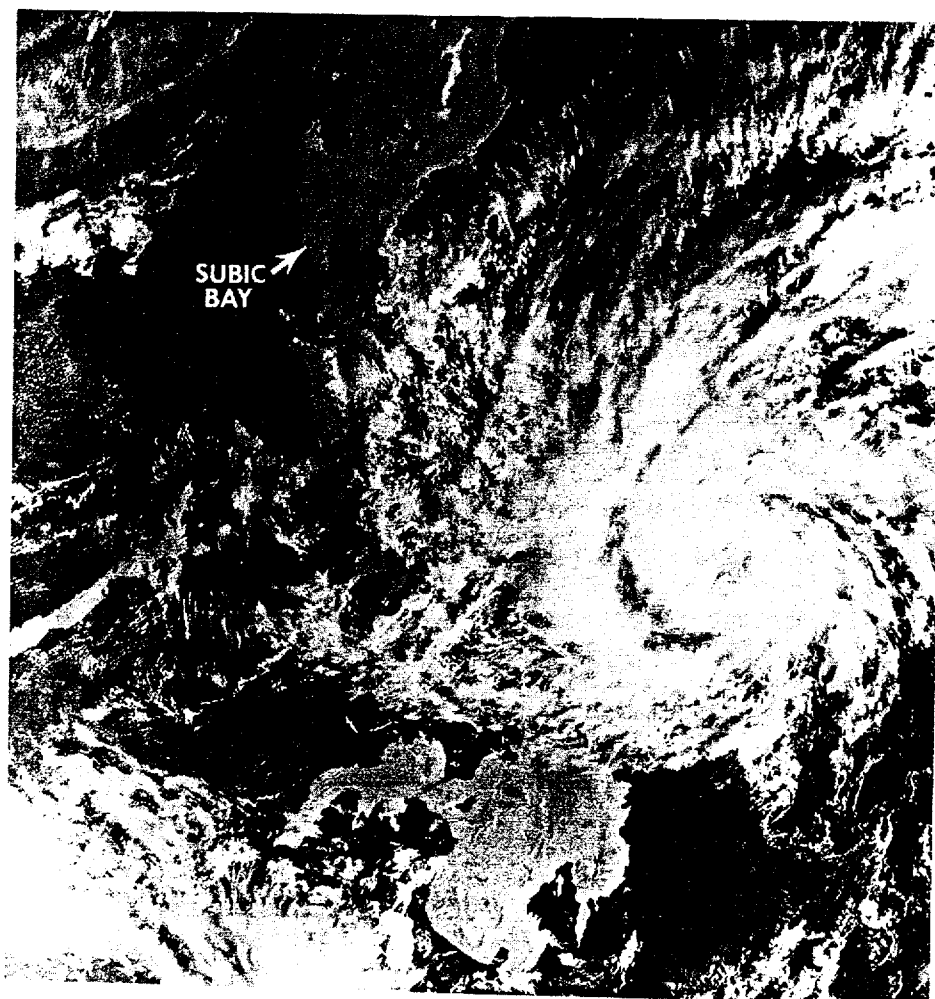


FIGURE 3-28-1. Tropical Storm Ben at 40 kt (21 m/sec) intensity, 21 October 1979, 0059Z. Ben was the last tropical cyclone in the western North Pacific during 1979. (DMSP imagery)



## 2. NORTH INDIAN OCEAN TROPICAL CYCLONES

During 1979, 7 significant tropical cyclones occurred in the North Indian Ocean area (Table 3-3). As usual, the transition

seasons between the northeast and southwest monsoon periods were the favored "cyclone seasons" (Table 3-4). This was an above normal season with most activity occurring during the fall transition period.

TABLE 3-3

### NORTH INDIAN OCEAN

#### 1979 SIGNIFICANT TROPICAL CYCLONES

<u>CYCLONE</u>	<u>PERIOD OF WARNING</u>	<u>CALENDAR DAYS OF WARNING</u>	<u>MAX SFC WIND</u>	<u>EST MIN SLP</u>	<u>NUMBER OF WARNINGS</u>	<u>DISTANCE TRAVELLED</u>
TC 17-79	06 MAY-12 MAY	7	85	967	26	1267
TC 18-79	18 JUN-20 JUN	3	50	985	12	581
TC 22-79	21 SEP-23 SEP	3	25	1000	10	694
TC 23-79	21 SEP-25 SEP	5	55	980	14	1108
TC 24-79	29 OCT-01 NOV	4	35	995	13	720
TC 25-79	16 NOV-17 NOV	2	40	994	8	547
TC 26-79	23 NOV-25 NOV	3	30	995	10	1071
1979 TOTALS		24*			93	

\*OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM.

TABLE 3-4.

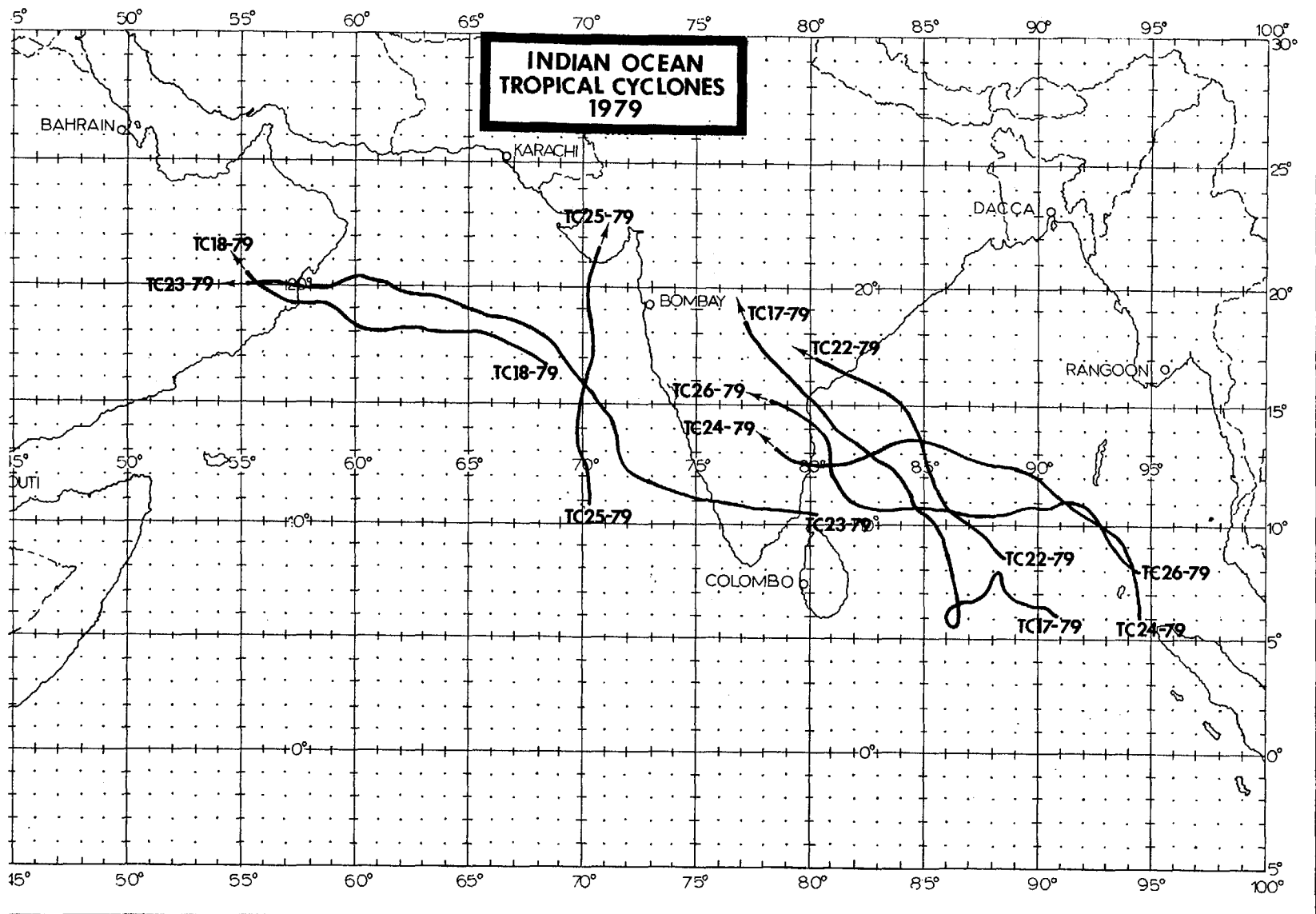
#### 1979 SIGNIFICANT TROPICAL CYCLONE STATISTICS

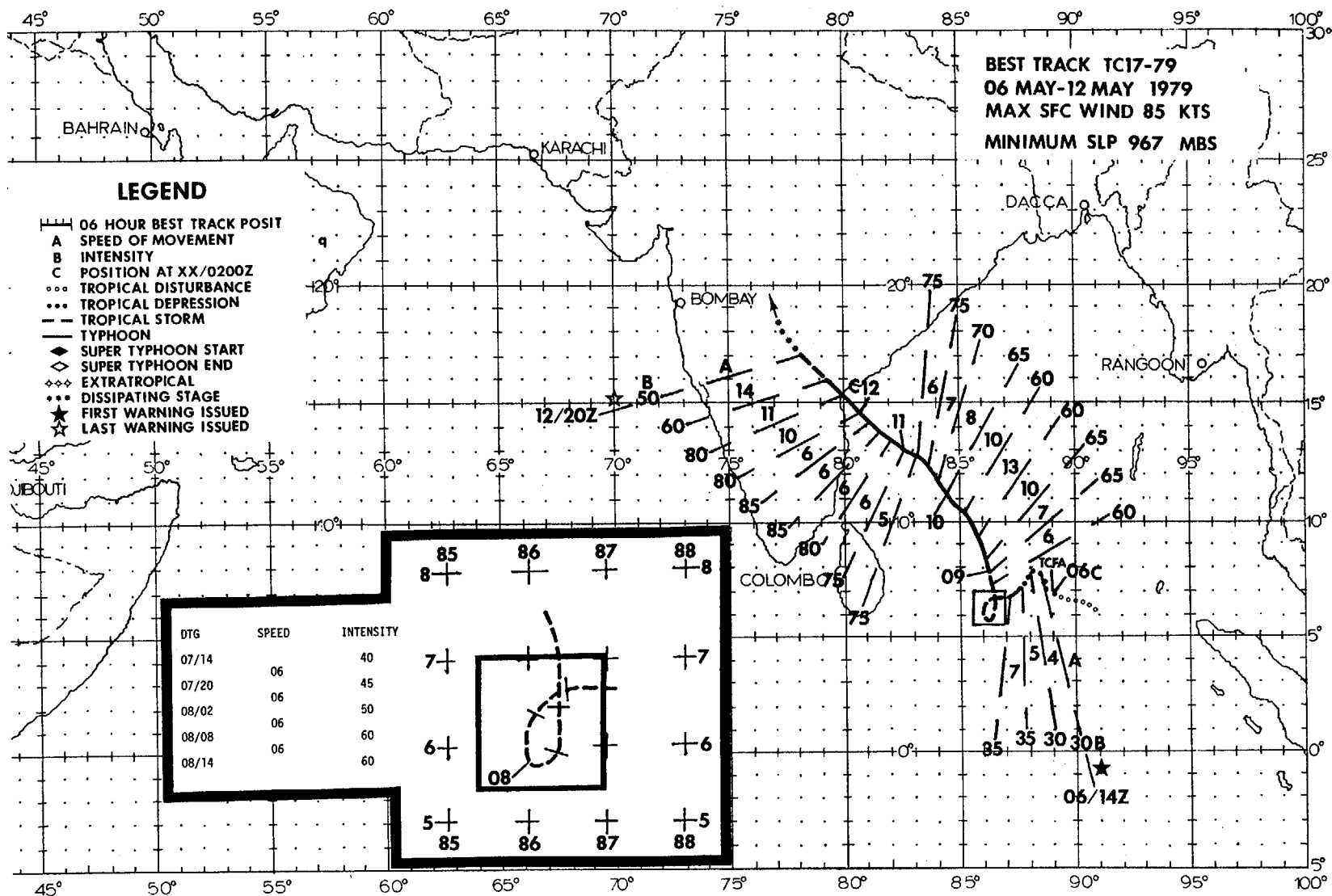
NORTH INDIAN OCEAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
ALL CYCLONES	0	0	0	0	1	1	0	0	2	1	2	0	7
(1971-78) AVERAGE*	0.1	0	0	0.3	0.5	0.3	0	0	0.4	0.8	1.4	0.3	4

FORMATION ALERTS 7 of the 8 (87%) Formation Alert Events developed into numbered cyclones.

WARNINGS  
 Number of warning days: 25  
 Number of warning days with 2 cyclones: 3  
 Number of warning days with 3 or more cyclones: 0

\*From 1971 through 1974, only Bay of Bengal cyclones were considered; the JTWC area of responsibility was extended in 1975 to include Arabian Sea cyclones.





TC 17-79 was the only significant tropical cyclone in the Bay of Bengal during the 1979 spring transition season. Attaining typhoon intensity, TC 17-79 was the most destructive cyclone in India since TC 22-77 (Nov 1977) which, coincidentally, followed a similar track.

A Tropical Cyclone Formation Alert and the first warning were precipitated by synoptic reports received from ships participating in the First GARP Global Experiment (FGGE). At 1200Z on 6 May, these ships' observations defined a cyclonic circulation near 07N-088E with reported surface pressures near 1003 mb and wind speeds of 20-25 kt (10-12 m/sec). The first warning on TC 17-79 was issued at 061507Z.

From 060000Z through 061200Z, a strong mid-tropospheric ridge extended westward along 15N with southeast steering flow dominating TC 17-79's movement. During the same time period, a short-wave trough, evident at both middle and upper levels, was deepening over India. Interaction between this ridging and troughing resulted in a loss of definitive steering flow in the vicinity of TC 17-79, producing an erratic north and then south track. Also during this time, TC 16-79 located in the southern Indian Ocean about 750-800 nm (1389-1481 km) to the southwest,

began tracking slowly to the southeast possibly initiating a Fujiwhara type interaction.

By 080000Z, a mid-level anticyclone had formed in the northern Bay of Bengal with east-northeasterly steering flow over TC 17-79 resulting in a west-southwest forecast track. From 080000Z through 090000Z, while TC 17-79 intensified (Fig. 3-29), the dominant steering flow shifted to the south then southeast as the mid-level ridge was replaced by a trough and the upper-level trough dug southward over India. As a result of this shift in steering flow, TC 17-79 executed a tight cyclonic loop from 080000Z to 081800Z. From 7 through 9 May, though satellite fix position accuracies improved due to the formation of a well-defined eye, forecast errors increased appreciably due to the erratic movement.

By 091200Z, southeast steering flow became dominant with TC 17-79 oscillating about a northwest track until making landfall over India (Fig. 3-30). TC 17-79 struck the east central coast of India at 120800Z, 45 nm (83 km) north of Nellore with maximum sustained winds of 80 kt (41 m/sec). Twenty-one deaths occurred and over 800,000 persons were left homeless as a result of TC 17-79's passage over the Nellore district.

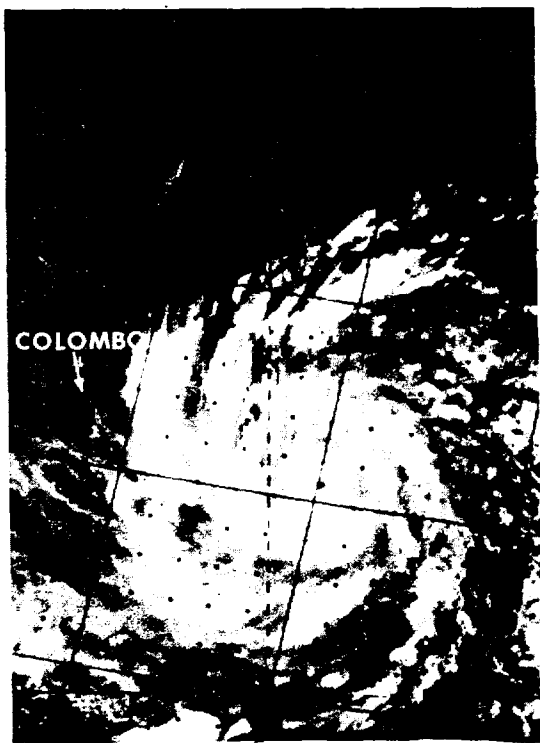


FIGURE 3-29. TC 17-79 with well-defined satellite signature during the erratic cyclonic loop, 8 May 1979, 0528Z. (DMSP imagery from AFGWC, Offutt AFB, Nebraska)

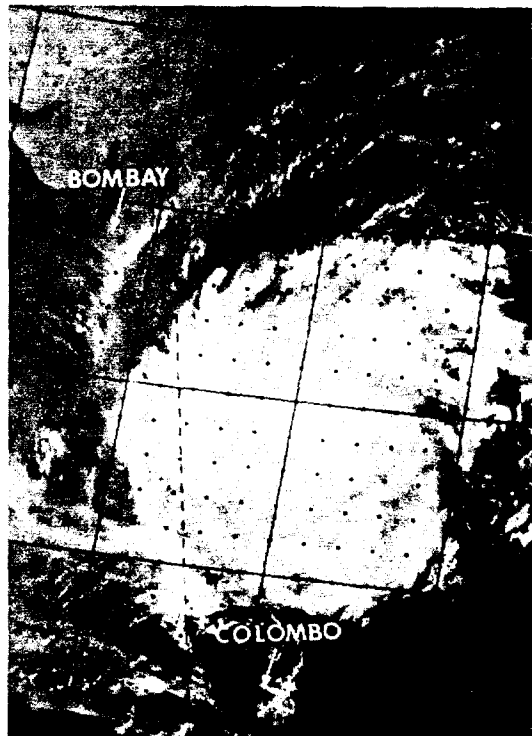
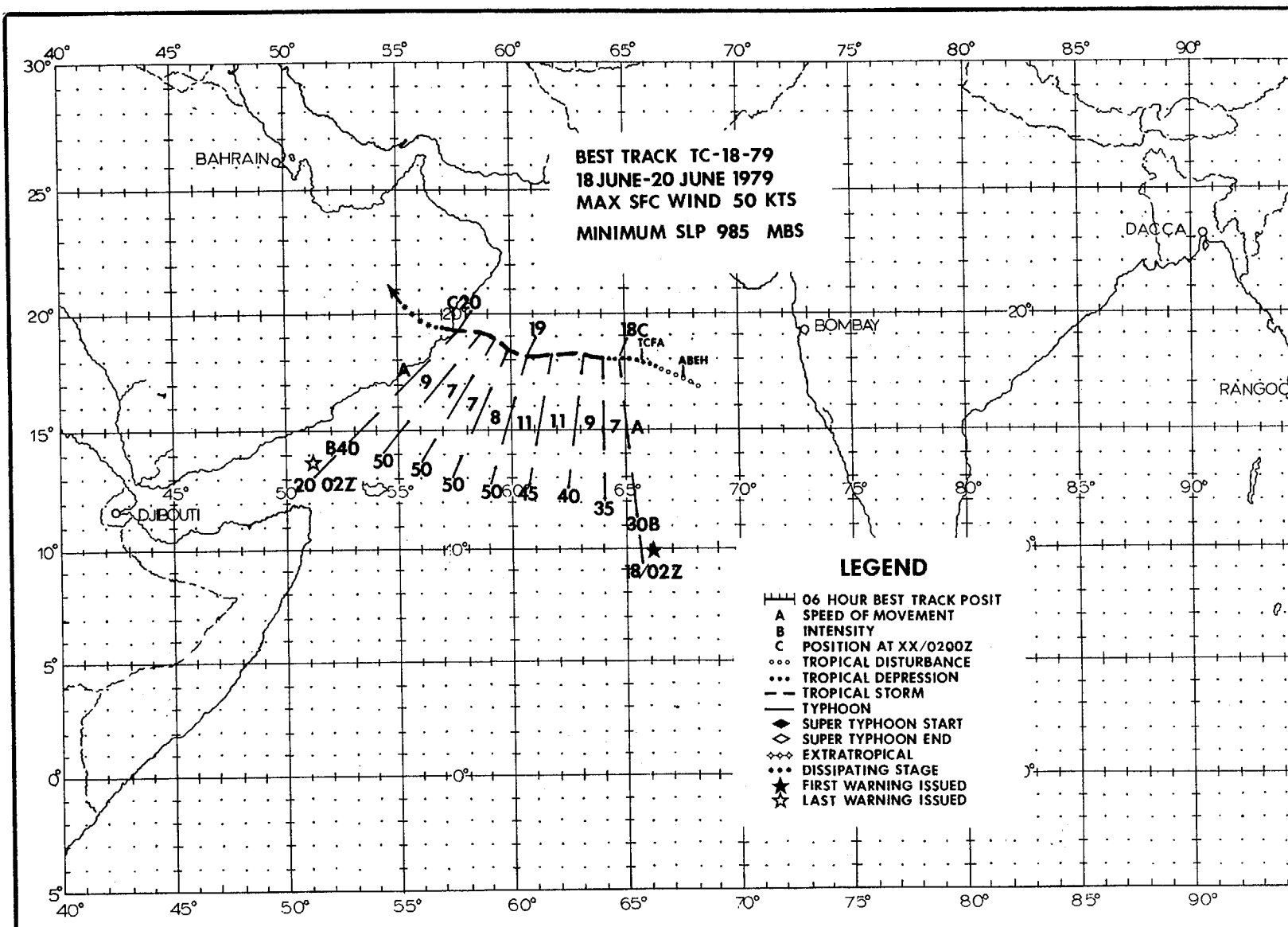


FIGURE 3-30. TC 17-79 just prior to making landfall over east central India with 80 kt (41 m/sec) intensity, 12 May 1979, 0556Z. (DMSP imagery from AFGWC, Offutt AFB, Nebraska)



# TC 18-79

TC 18-79 began 171400Z June 1979 as a monsoon depression in the Arabian Sea and tracked virtually westward throughout its life, finally dissipating over the Oman coast (Fig. 3-31). Although TC 18-79's movement was confined to a narrow 2-degree latitudinal band, the extent of the meteorological hazard from gale force winds encompassed roughly half of the Arabian Sea. These gale force winds were produced by the interaction of TC 18-79 with the normal southwest monsoonal flow over the Arabian Sea.

During this season, a climatological low-level wind maximum develops off the coast of Somali. Normal wind speeds can reach 35-40 kt (18-21 m/sec), but the gale area is generally localized near the coast. However, beginning 2 days prior to TC 18-79's forma-

tion, a surge in the monsoonal flow occurred and a low-level jet could be traced from the Somali coast extending eastward across the entire Arabian Sea. The strength and persistence of this feature aided the formation of TC 18-79 in the cyclonic shear side of the wind maximum. As TC 18-79 intensified and moved westward, the southwesterly flow strengthened to a point where 65 kt (33 m/sec) surface winds were observed 600 nm (1111 km) away from TC 18-79's center. Examination of the visual data of Figure 3-31 shows cloud streets indicative of this strong low-level flow from 05N to 12N between 55E to 62E. The gale area persisted during TC 18-79's dissipation over land, weakening gradually with time. Interestingly, post-analysis reveals the maximum winds in the gale area exceeded the maximum sustained winds estimated in TC 18-79's center.

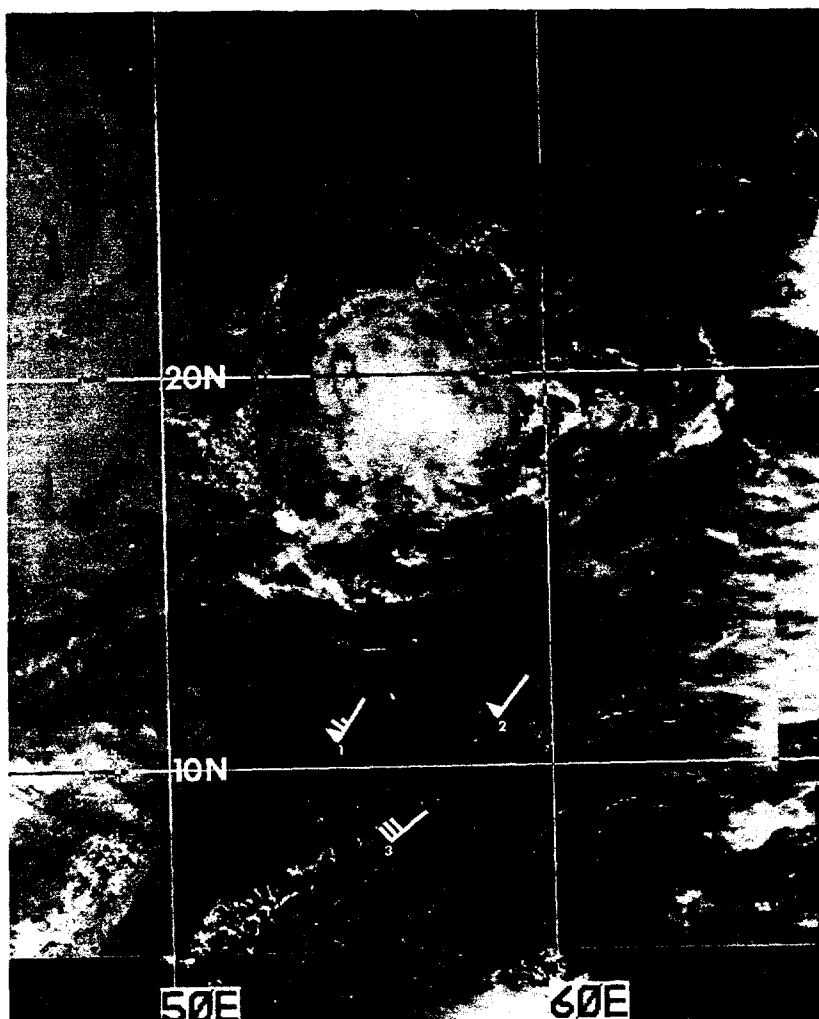
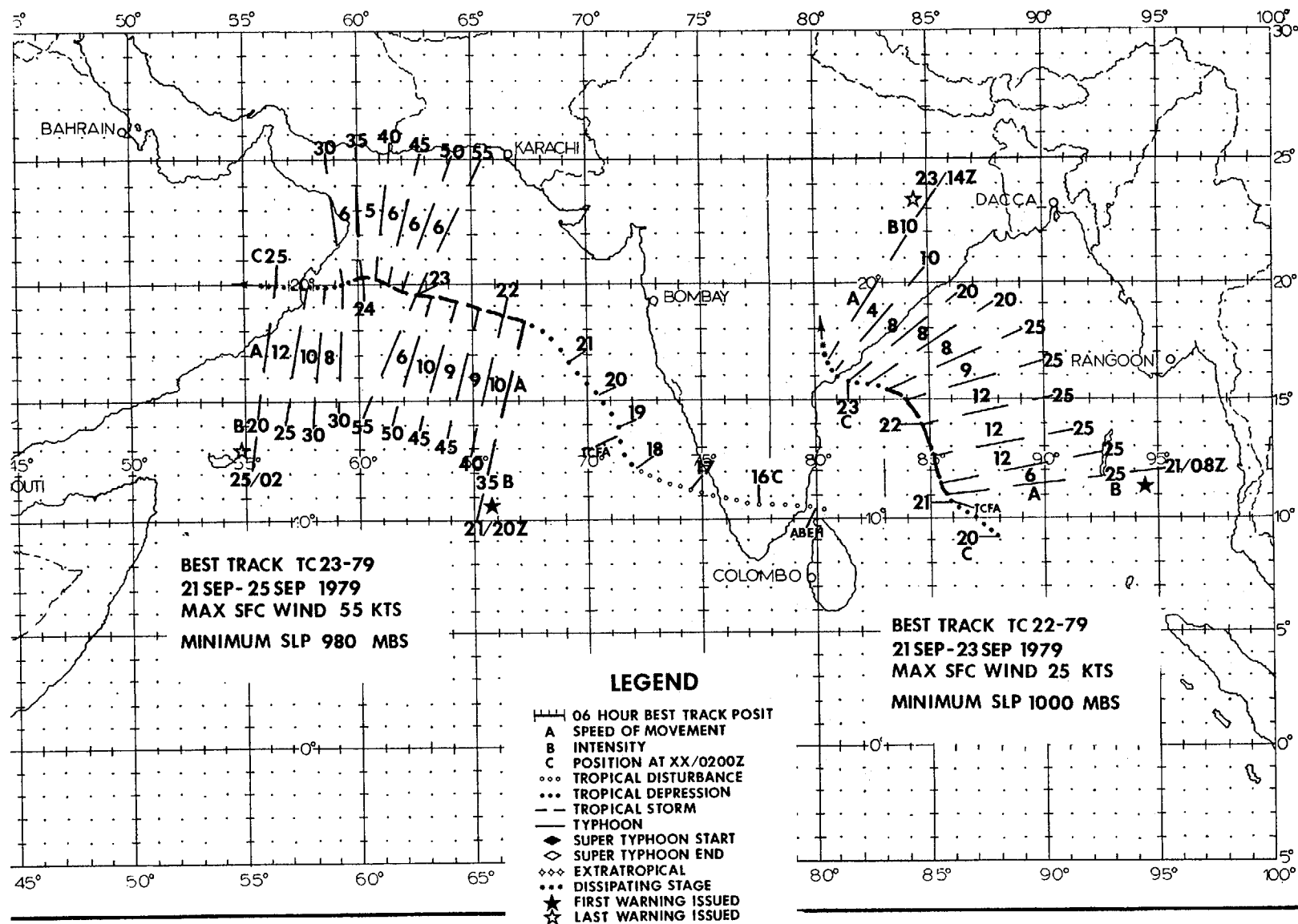
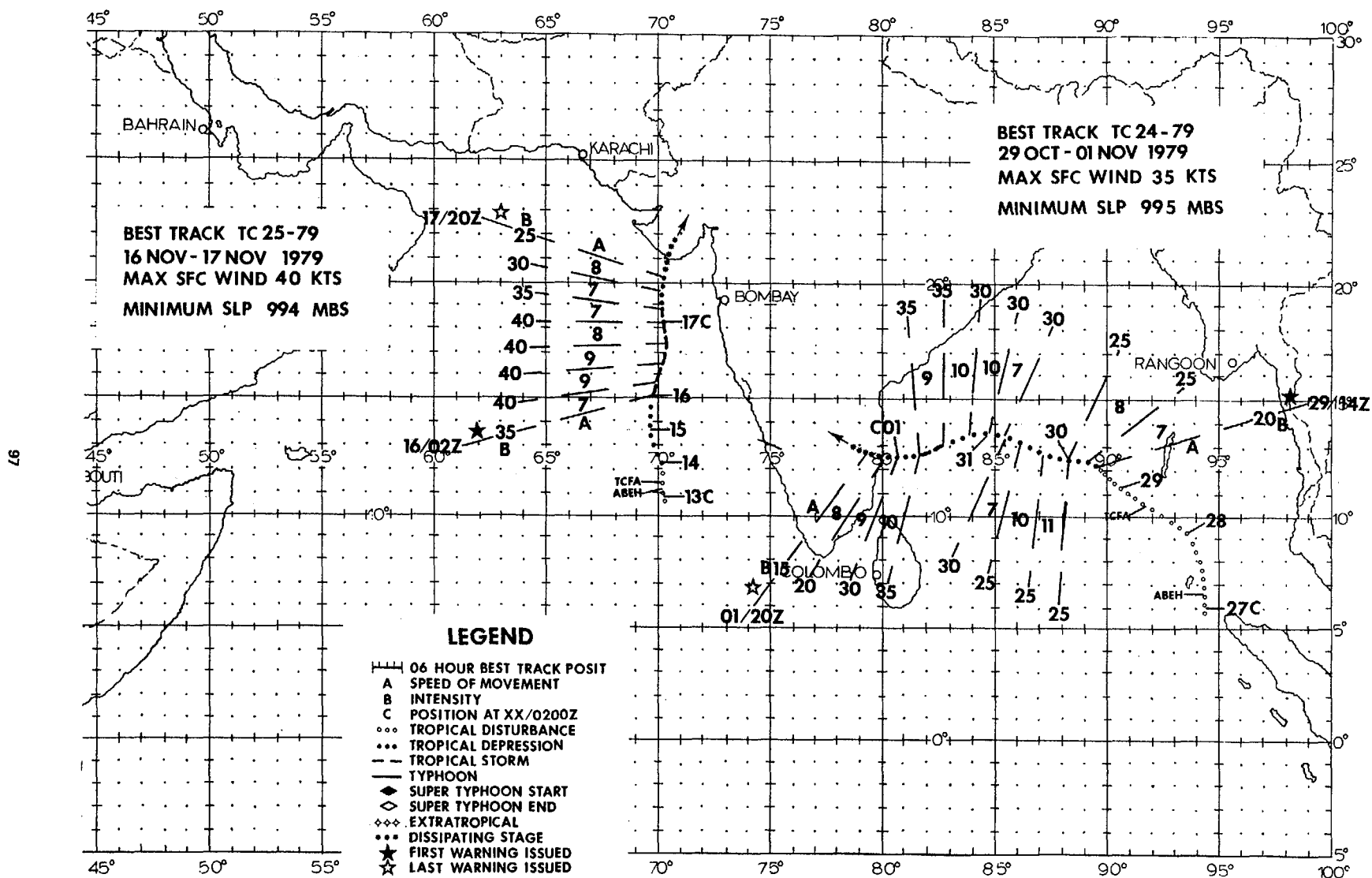
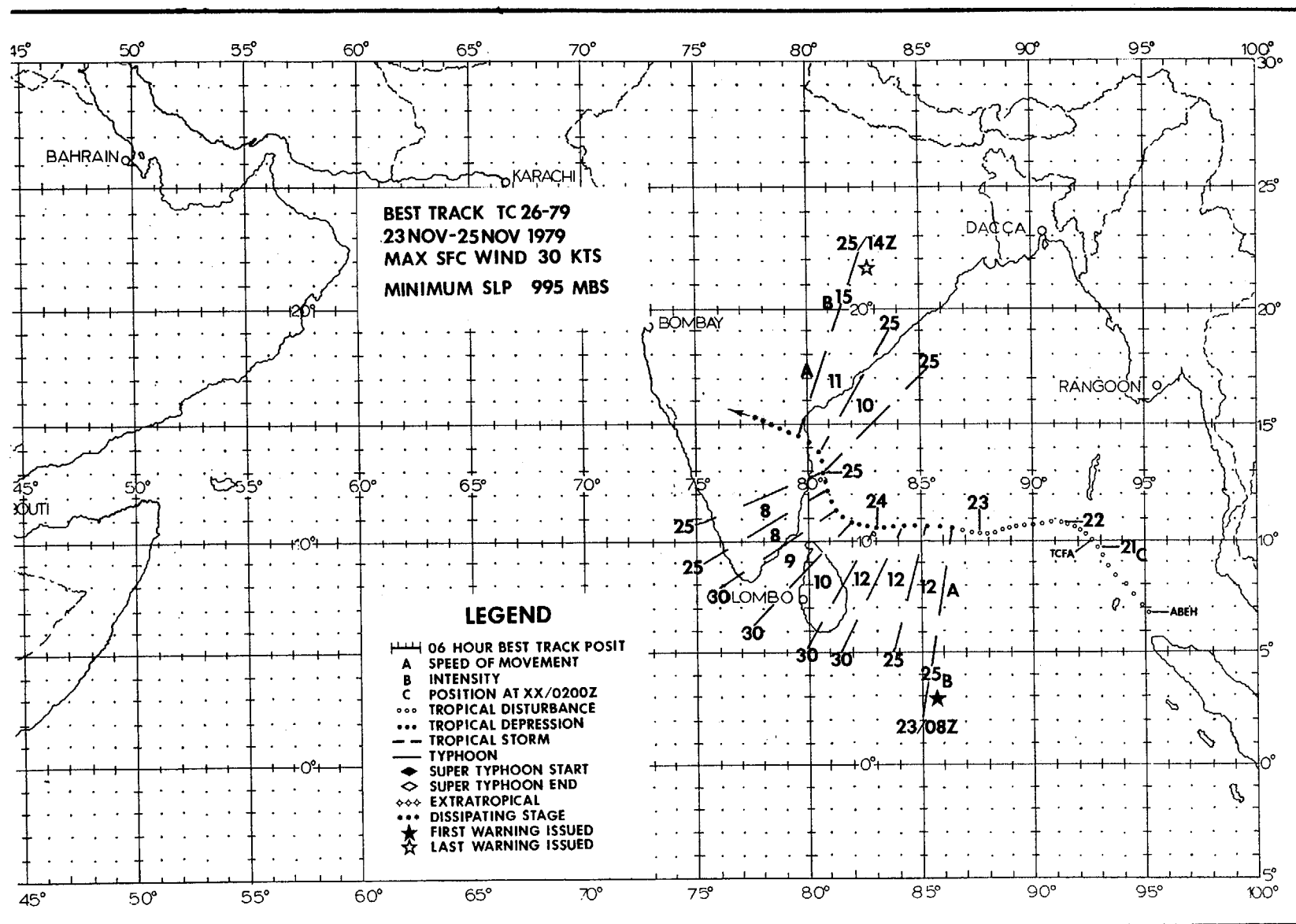


FIGURE 3-31. TC 18-79 located just off the Oman coast with gale force winds to the south, 20 June 1979, 0731Z. Superimposed are ship observations at 200600Z. (DMSP imagery from AFGWC, Offutt AFB, Nebraska)









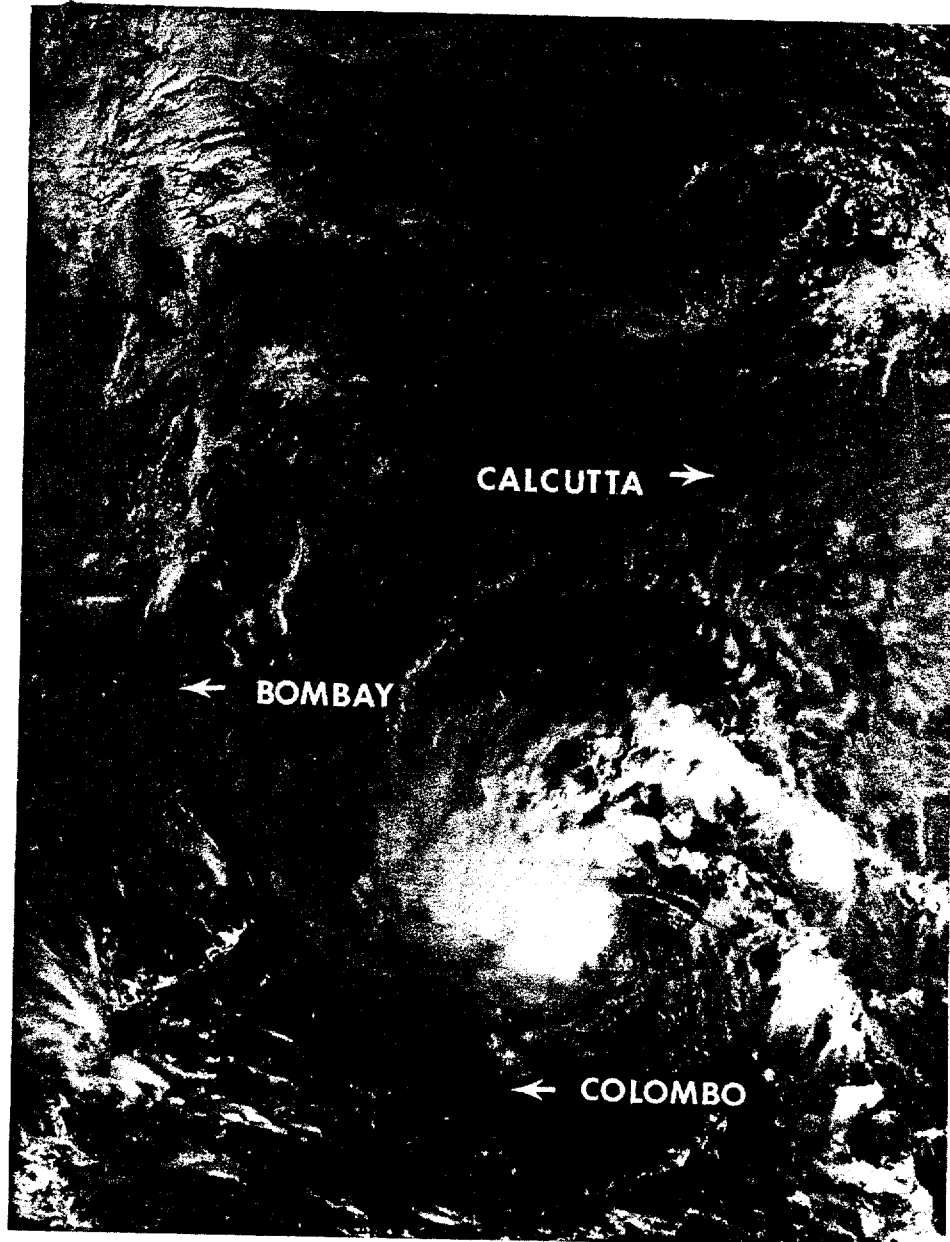


FIGURE 3-32. TC 26-79 as an exposed low-level circulation, 24 November 1979, 0455Z. [DMSP imagery from AFGWC, Offutt AFB, Nebraska]